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TABLE OF CONTENTS.

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ERRATA.

P. 91, line 10 from below, for found read formed.
P. 96, line 7 from below, for bud read ends.
P. 191, fig. 3 is 1.5 times actual size.
P. 220, line 14, for multidudinous read multitudinous.
P. 222, line 4, for *Polyporus fomentarius* read *P. laricis* (Jacq.).
P. 255, line 6, for cylindrica read cylindrico.
P. 258, line 6, for Pitterian read Pitteriana.
P. 262, line 21, for filiforms read filiformes.
P. 355, line 8, for stimulate read simulate.
P. 358, lines 18 and 19, for per second read per minute.

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BINUCLEATE CELLS IN CERTAIN HYMENOMYCETES.

ROBERT A. HARPER.

(WITH PLATE I)

INCLUDING the basidia and spores, Rosenvinge found that the cells of the Basidiomycetes contain from one to many nuclei. He was of the opinion that the uninucleated condition is typical and that only the uninucleated cells divide, the multinucleate condition arising secondarily by division of the originally single nucleus of each cell.

Two notes by R. Maire (9, 10) in the *Comptes Rendus* of July 9 and December 24, 1900, report that the hyphal cells of the young carpophore in a large series of Hymenomycetes are regularly binucleated. This discovery throws a new light on the question as to the nature of the nuclear fusions in the basidium, and indeed on the whole question of the morphology of the carpophore. In view of the many times suspected relationship of the Basidiomycetes and Ascomycetes and the seemingly natural assumption of the equivalence of the nuclear fusions in the ascus and basidium, my own work on the ascus led me to desire further confirmation of the results given by Maire, and especially further light on the number and nature of the nuclei in the mycelium as well as the carpophore of the Hymenomycetes. In his first note Maire describes observations on a series of nine genera of Agaricineae, Polyporeae, etc. In all these genera he finds that the mycelial cells of the young carpophore

are binucleated. In the mature carpophore the majority of the cells in the stipe and pileus are multinucleate, but this condition arises from the amitotic fragmentation of the two nuclei originally present in each cell. The subhymenial cells from which the basidia spring and the paraphyses are always binucleate. This involves the remarkable fact that all the cells which are directly concerned in producing the basidiospores are throughout their development binucleated. In other words, all the cells of the *Keimbahn* are binucleated, the multinucleated condition only arising in cells of strictly limited development and found in the organs of nutrition, support, transportation, etc. Maire also finds that the pairs of nuclei divide simultaneously as "conjugate nuclei" (12), so that in the successive cell generations which arise in the development of the carpophore the two nuclei in each cell are always of widely separated nuclear ancestry, the whole condition duplicating exactly what has been described by Dangeard and Sappin-Trouffy (3) and Poirault and Raciborski (12) for the rusts. Further, in the young basidium two and only two nuclei are always present, just as in the teleutospore of the rust. These two nuclei fuse to form the primary nucleus of the basidium, which then divides twice to furnish the nuclei for the typically four basidiospores. The descriptions of Rosen (13) and Wager (16, 17), according to which a series of nuclei fuse successively in pairs to form the primary nucleus of the basidium, are entirely incorrect according to Maire for the large series of forms examined by him.

In his second note Maire describes observations on a series of Gasteromycetes, in which he finds exactly the same conditions as described above for the Hymenomycetes.

Maire believes that the fusion of nuclei in the basidium is without doubt sexual in its nature, since the pronuclei which unite are of widely separated origin, although passing the whole course of their development in a single cell series. These facts bring the carpophore of the Basidiomycetes into closest parallelism with the whole life cycle of the Uredineae, both as to the nature of their vegetative cells and in the similarity of the

processes in the basidium with those in the teleutospore and promycelium. The only marked difference is in the fact that the promycelium of the rusts is a septate basidium with lateral spores instead of a one-celled basidium with apical spores. Should Dangeard's (2) claim that the vegetative cells of the so-called Protobasidiomycetes are binucleate be confirmed, a very complete parallelism would be demonstrated between the latter and the rusts of the Coleosporium type. Maire says little of the mycelia of the Basidiomycetes which he has studied. The mycelium of *Coprinus radiatus*, however, he says, has uninucleated cells; where the transition from the uninucleated to the binucleated condition occurs he does not say.

Maire describes at some length the division of the nuclei in the basidia. The pairs of nuclei as they divide in the mycelium have each four chromosomes. The fusion nucleus in the basidium shows four chromosomes, both in its first and second divisions. The accuracy of these points can be better judged when the author publishes his figures. He also describes a peculiar and interesting behavior of centrosomes at the time of the formation of the sterigmata. The centrosomes lie at the points on the basidial wall where the sterigmata are to bud out. From these centers fibers differentiated out of the cytoplasm extend to each of the four nuclei which lie at the base of the basidium. Under the influence of these fibers the nuclei gradually approach the vertex of the basidium.

In the light of Maire's observations it becomes probable that the observations of Strasburger (15), Rosenvinge (14), Istvánffi (8), and others, according to which the cells of the Basidiomycetes are regularly multinucleated, were based only on a study of the old vegetative cells of mature sporophores, whose multinucleated condition is secondary and developed in connection with their special enlargement as supporting cells for the variously placed hymenium. Wager says very little as to the nuclei of the vegetative cells and does not describe the condition of the subhymenial cells, though he describes the hyphal nuclei as wandering into the young basidium in pairs (17). His

descriptions relate mainly to the phenomena in the basidium, but he has figured (17, *pl. XVII, fig. 1*) part of a hyphal cell with a pair of nuclei, which from their position and size suggest that they may be the only nuclei in the entire cell.

An investigation, not yet published, of the structure and development of *Tremella mycetophila*, parasitic on *Collybia dryophila*, by a student in my laboratory, showed that the carpophore of the Collybia contained regularly binucleate cells.

The species of Hypochnus, owing to their simple structure and the loose branching habits of their basidium-bearing hyphae, are very favorable material for the investigation of the nuclear phenomena in the mycelium and young hymenium. Species growing on very rotten wood are specially adapted for good fixation and sectioning. A species agreeing fairly well with *Hypochnus subtilis* Schroet., except that the setae are brown, is abundant in this region. The material in all stages of development from vegetative mycelium to well-developed hymenium with ripe spores can be readily obtained in the fall months.

My material was fixed in Flemming's and in Merkel's solutions, and was sectioned and stained with the safranin-gentian-violet-orange method.

It became apparent at once, as was to be expected, that the cells of Hypochnus, which develops no carpophore of sterile tissue, were regularly binucleate throughout, with the exception of the old stalk cells of the cystids and perhaps the cystids themselves. The conditions in this respect duplicate as nearly as possible those in a rust of the type of *Coleosporium sonchi-arvensis*. As is well known, the genus Hypochnus includes a group of the very simplest known Hymenomycetes. The mycelium ramifies in the substratum of decaying wood or rich earth and produces a simple hymenial layer on its surface made up of basidia alone, or, in some species, with intermingled cystids. As the genus is described, there is nothing to represent a carpophoric structure.

The hymenium is itself quite loose. At first it consists merely of scattered, erect basidium-bearing hyphae, which are

readily isolated and show a basipetal habit of branching, very well represented in the figure (*137*, p. 301) of De Bary's *Handbook* (4). The successive development of such erect hyphae and their becoming interwoven and pressed together results in the formation of the hymenial layer. At first these erect fertile hyphae can be readily isolated and studied in the living condition, as was done by the older authors, the entire system of branches from a single main trunk being thus very easily and accurately worked out, as shown so well in the figure referred to above. In stained sections, too, these earlier tree-like fertile branches stand out with beautiful distinctness, and show basidia in all stages of development, and with their nuclei in all conditions. The order of succession in the development of the basidia can be traced with perfect accuracy. Later, as the hymenial layer becomes more dense, these individual twig systems can be no longer differentiated, though there is no question that the further development consists in nothing more than the pushing up of additional erect hyphal branches among those earlier developed. The species investigated forms a delicate frost-like growth on the surface of very well rotted logs, and should be collected in damp weather. The substratum was so soft as to offer no special resistance in cutting, and it was therefore possible to take off thin slices of the substratum several millimeters square and fix them with practically no disturbance of the fungus.

The mycelium was found ramifying through the decayed wood cells in all directions. The peculiar clamp connections, described by Hoffman (7) between adjacent cells of a hypha, were abundant. In fact, they seemed to be present at one or both ends of nearly every cell. Brefeld (1) has described these clamps in Coprinus as originating in a tube which pushes out from the end of one cell, bends over, and fuses with the end of the next adjacent cell. Brefeld finds that before the clamp tube fuses with the second cell it is separated from its parent cell by a septum. Later he finds also that a second septum is put in, replacing the walls broken down in the fusion. The mature clamp is thus cut off by a septum from each of the two

cells which it connects. I have not observed the development of these clamp connections in Hypochnus, but in the mature condition as they are universally found in my material they show but one septum, and that apparently on the cell from which the clamp-tube originated. The significance of these structures is not clear. Presumably they facilitate the transfer of excess food materials and moisture from one cell to another, but just how they are adapted to this function is not evident from their structure. I have not observed in Hypochnus the granules or plates on the septa between adjacent cells which are so common in many Basidiomycetes and Ascomycetes (5, 7), and which probably indicate the location of some sort of pores for communication between the hyphal cells. In Coprinus, as we shall see later, such plates are present in great abundance, and have a very characteristic appearance.

The mycelial cells of Hypochnus vary considerably in length, though of fairly constant diameter in the mature mycelium. A cell of about average proportions is shown in *fig. 1.* In the specimens studied the hyphae formed no dense wefts or strands in the substratum. On the whole it seemed rather loose and sparse. The vessels of the decaying wood with their large empty cavities afforded a favorable opportunity for studying the hyphal cells, the hyphae cutting through these cavities in all directions, but never filling them densely. The mycelial cells are practically without exception binucleate. The two nuclei generally lie rather close together and near the center of the cell, but they may be at opposite ends, or otherwise placed in the cell. *Fig. 10* shows that, however the pair may be located in the cell, they are generally rather close together. These nuclei show, in well-stained preparations, a nucleole and chromatin sharply differentiated, and are sharply bounded by a nuclear membrane.

Fusions (6), such as have been described by many observers between cells that are near together or in contact, are quite common in Hypochnus. There is no clear evidence that in this case they have any other significance than as channels for the

interchange of food materials, etc. Such a fusion is shown in *fig. 10*, in the lower right-hand part of the subhymenial tissue.

The mycelium of Hypochnus in the case studied forms no felt of hyphae on the surface of the substratum, apparently, until the time has arrived for the formation of basidia. That is, through its purely vegetative existence it is entirely buried. When the hymenium is to be formed, erect aerial branches are pushed up, and branch into the tufts referred to above as figured by De Bary. The main axes of these tufts are never close packed, but arise from the substratum at relatively considerable distances from each other. Their abundant interlacing branches, however, form a dense hymenial layer higher up. We have thus a condition in this respect resembling a diminutive forest, or growth of shrubbery, whose branches and twigs are densely interlaced, while the trunks from which they arise are separated by relatively wide open intervals. This is shown, with a modification noted below, in the semi-diagrammatic *fig. 10*. The whole mass of the hymenium here shown is supported by the three hyphae arising from the substratum. The figure, to be sure, is of a section, so that part of the hymenial cells belong really to other twig systems arising above or below the level of the section. A corresponding portion of the branches of the two main hyphae figured lie also above or below the section, and hence do not appear, so that the proportion of peripheral branches to main axes as shown is not materially affected. The case is further complicated frequently by proliferation from the surface of an old and apparently exhausted hymenial layer. This is the condition shown in the figure in question, where the hymenium which shows the immature basidia has been superimposed on the surface of an older one. The upper surface of the latter is very clearly indicated, and it is at once seen that the same method has been employed in forming the second hymenial layer as in the first case. The old hymenium has become the substratum out of which arise scattering vertical hyphae, which by their copious branching then form the new hymenium. The old hymenium is seen to consist of a mass of hyphal cells very

poor in content which have replaced the basidia. The latter, as in all true Basidiomycetes, collapse soon after their spores are ripened.

Whether this habit of forming new hymenia by proliferation from those already exhausted is due to alternation of favorable and unfavorable conditions of moisture, etc., I am not sure. It is also uncertain whether a single hymenial layer may go on indefinitely producing new basidia to replace those which have ripened their spores as long as conditions are favorable for growth. Such continuous unlimited growth is quite possible by the basipetal method of branching shown in De Bary's figure. It would not result, however, in the formation of a second new hymenium, such as is shown in *fig. 10*, and it seems quite probable that the latter has been secondarily formed after a check to growth due to cold or drouth sufficient to stop the formation of basidia in the first hymenium. Whether a third hymenial layer might be developed in the same manner I have not determined. No such case has been found in the material so far studied.

It is interesting to note that, although the structures described for Hypochnus are extremely delicate and of microscopic size, the process of forming the new hymenial layers is essentially the same as that found in the larger stratified Polyporeae. Hypochnus, as we see, is really stratified, though not so described, and though lacking any markedly differentiated pileus. In the large woody fungi of the stratified Fomes type the new hymenial layers are formed as layers of pores and in successive seasons. But the method of their development by proliferation of new basidium-bearing hyphae from the old mycelial tissue of the previous season is essentially similar to that described above (so far as is known), except that the process is on a larger scale in Fomes, and the layers formed are of visible thickness.

If we look more closely now at the actual method of branching of the basidium-bearing hyphae of Hypochnus, we find, as indicated above, that the new branches are regularly produced basipetally. Each end cell becomes a basidium, and before this

apical basidium is more than half developed the cell beneath it pushes out a new basidium (*fig. 4*) which grows up beside the first. Later a second (*fig. 3*), and in some cases even a third, basidium may bud out on different sides and just beneath the basal wall of the first basidium. This gives the appearance of a stalk cell bearing a cluster of basidia at its apex. Since these basidia are pushed out successively, however, and their formation consists essentially in a process of cell division, the whole cluster represents really a basipetal series. The stalk cell becomes successively, at least as far as the nuclei are concerned, the sister-cell of each developing basidium as it is cut off. At the same time, from cells below the stalk cell of the first basidium lateral branches may be given off and grow to a length of from one to several cells, according to the level at which they arise from the main axis. Still further branchlets may arise from the cells of these lateral branches. In the end the apical cells of all these branches become basidia, and just beneath the septa which cut off these basidia one or two further basidia bud out. The basidium terminating the main axis of such a system is always the oldest and ripens first. The clusters produced on the lateral branches push up to the height of the main ax's, but not higher, and ripen successively. The whole process is easily understood from a study of De Bary's figure and *figs. 2–4, 7, 9, 10*. With reference to their method of branching, we may compare such hyphal systems with their basidia to a flat topped cyme among the flowering plants.

The entire fruit body of Hypochnus is composed thus of a series of such cymosely branched hyphal systems, whose branches are intricately interlaced and packed together. Such a hymenium is strictly a compound structure made up of a series of similarly branching fertile hyphae. The only unity to be found in it lies in the fact of its possible origin from a single mycelium produced by the germination of a single basidiospore. As a matter of fact, it is highly improbable that such unity as this ever really exists in any given case. It is much more likely in the majority of cases that mycelia from different spores are

mingled in the substratum, and that any particular hymenial layer is made up of fertile branches from different mycelia. Their ability to combine into the even homogeneous films extending over many square centimeters would be wholly due to their similar environment and their mutual interaction, and not to any unity of origin, since each mycelium must be regarded as an independent plant.

It is plain that this conception of the Hypochnus hymenium as a compound having no strict individuality is of great importance for determining the morphological value of the more complex carpophores of the higher Basidiomycetes, and in comparing them with the fruit bodies of the Ascomycetes, which arise typically at least as units from the cell or cells of a sexual apparatus, so far as their fertile ascus-bearing hyphae are concerned.

The cells of the hyphae which occupy the place of the old hymenium in *fig. 10* are very poor in protoplasmic content. Among them are the empty and partly collapsed cell walls of the old basidia, which are scarcely recognizable, owing to the growth and crowding of the new mycelial tissue. How this new growth arises from the subbasidial tissue I have not been able to make out. The old basidia and their connections cannot be traced at all definitely at such a stage as is represented in *fig. 10*. There is no reason for anticipating anything especially noteworthy in the details of such a proliferation. The fact that it occurs, however, is a still further point of difference between the Ascomycetes and the Basidiomycetes. The former never show such secondary hymenia developed on the surface of old hymenia. The ascogenous hyphae show frequently a protracted, but none the less ultimately a definitely limited, growth, resulting in a characteristic fruit body, the ascocarp; while the merely vegetative hyphae which bear the basidia may prolong and repeat at intervals the development of new hymenial layers.

The stromata of Diaporthe, and other similar types which may show more or less secondary growth, are not ascocarps, but vegetative mycelia bearing ascocarps imbedded in their substance (18).

The cells of the old hymenium, like those of the mycelium buried in the substratum, contain regularly two nuclei. These are usually placed rather close together, as noted above. The apical cells which are to form basidia contain regularly two, and only two, nuclei. I have found no exceptions to this rule, though doubtless such occur as abnormalities, as pointed out by Maire. The young basidium is also regularly separated from its stalk cell at an early stage, so that in Hypochnus there is no chance for such a migration of pairs of nuclei as Wager thinks probable. The conditions are especially favorable in Hypochnus for determining this point. In the subhymenial tissue of the agarics the hyphae are so densely packed, in many cases forming a pseudo-parenchyma, that it is difficult to trace the path of a single hypha for any distance, or to determine just what the connections of the basidium at its base may be. In Hypochnus the loose branching makes it possible to determine just how and when each basidium has been formed and cut off, and it is certain for this case that Maire's general statement that two, and only two, nuclei are cut off in the young basidium is true, as opposed to those of Rosen (**13**) and Wager (**16**). The stalk cells also contain two nuclei. The conditions just described are well illustrated in *figs. 2, 3*, and *7*.

Whether the two nuclei of the cell from which the basidium is cut off divide simultaneously, and whether simultaneous nuclear division ("conjugate nuclear division" of Poirault and Raciborski [**12**]) occurs generally in the formation of new cells in the mycelium, I have been unable to determine with certainty. That this is the rule in the case of the binucleated cells of the rusts there can be no doubt. The work of Dangeard and Sappin-Trouffy (**3**) and Poirault and Raciborski (**12**) establishes this fact and I have been able to confirm for myself their results on this point. As to the details of the so-called conjugate division, however, the figures so far must be considered as very unsatisfactory. The evidence presented by Sappin-Trouffy and by Poirault and Raciborski is not at all convincing on any points further than that the nuclei lie side by side and divide simultaneously.

In the same way I have also found great difficulty in obtaining satisfactory figures of the nuclear division in the cell from which the basidium is cut off, and prefer to reserve judgment on the whole process until more satisfactory methods of preparation have been worked out for this material. Maire in both his papers referred to describes the nuclear division as of the conjugate type, the same as in the rusts. Still the evidence is not clear, and in the formation of the secondary basidia, which bud out from the stalk cell of the one first cut off, figures are not uncommonly found which point to a different process. For example, in *fig. 4* it is seen that one nucleus is already in the young basidium, while one has remained in the stalk cell. It would seem as if the next step would be the division of these nuclei *in situ*, giving two sister-nuclei, for the young basidium and another pair of sister-nuclei for the stalk cell.

The stalk cells contain quite regularly two nuclei after the basidia have been cut off (*figs. 2* and *7*). I have also found a number of cases in which the two nuclei of the mother-cell of the first basidium of a cluster were dividing simultaneously. The figures, however, were dense and unsatisfactory, resembling the figures of the conjugate division in the rusts referred to above; and, while affording evidence of simultaneous division, are not, in my opinion, to be regarded as at all typical. Maire states that all the Hymenomycetes studied by him show four chromosomes in these mycelial nuclei, but in the absence of figures it is difficult to judge of the evidence on which this conclusion is based.

The pair of nuclei in a young basidium grow rapidly with the growth of the basidium. This very notable increase in their size seems to have been regarded by Wager as suggesting the likelihood of repeated nuclear fusions, but the phenomenon is not different from that in Synchitrium, where with the growth of the fungus cell the nucleus grows until from being one of the minutest of nuclei it becomes much larger than the nuclei of the host-plant cells which surround the fungus. The significance of such changes in nuclear volume is not clear, but they

are regularly correlated with increased size in the cell to which the nucleus belongs.

Fusion takes place generally when the basidium has reached from one-half to two-thirds of its mature size, though wide variations from this rule may be observed. The process can be observed readily in all stages. The nuclei become flattened upon each other. The nuclear membranes disappear over the area of contact and the nuclear cavities become continuous. The fusion nucleus shows a constriction for some time around the area of union. This furrow gradually disappears and the nucleus is evenly oblong oval in outline. Later it becomes more spherical, regaining the shape which it had before fusion took place.

Just how the chromatin masses are combined cannot be made out. They become apparently continuous in the region of contact as soon as the membranes have disappeared. Later no line of demarcation between the two can be made out. Still I am inclined to believe that the appearances of homogeneity are not to be taken as conclusive evidence on this point. There seems little doubt that the nucleoles fuse. They are conspicuous, sharply defined objects clearly differentiated as clear red spheres in the blue chromatin throughout the whole process of fusion. Each of the nuclei before fusion appears with astonishing regularity as possessed of one nucleolus (*figs. 2–4*), and just as regularly the spherical fusion nucleus shows a single and frequently much larger nucleolus. During the earlier stages of fusion the two nucleoli are still present (*figs. 5, 6*). They are frequently found later close together and pressed upon each other, though such figures as these are not to be considered as having great weight in view of the irregularity in shape which nucleoli frequently show. The fusion nucleus increases still further with the further growth of the basidium. It lies generally in the mature basidium at about two-thirds the distance from the base to the apex.

The stages in the division of the nucleus have been very fully described by Wager. They are abundant and easily found

in Hypochnus. In general, the karyokinetic figures agree with those found in the division of the ascus nuclei. A more detailed account of the stages I shall give later in another connection. The fusion nucleus regularly migrates to the apex of the basidium before it divides. The spindle is always transverse to the long axis of the basidium. In the equatorial plate stage and a little later the chromosomes are well individualized on the spindle, and the number seems to be at least from eight to twelve before the anaphases begin, as shown in *fig. 8.* Maire gives four as the number of chromosomes appearing in the division of the nucleus of the basidium in the long series of forms studied by him. It is certain that there are many more than four chromosomes in the nucleus of the basidium of Hypochnus. The second division immediately follows the first, and the spindles here are also transverse to the long axis of the ascus.

The four daughter nuclei then retire downward to about the middle of the basidium, while the basidium stretches up still farther in length, and the sterigmata bud out around its apex (*fig. 9*).

Maire has described strands of fibers (kinoplasm) connecting each nucleus with the point of origin of a sterigma. He interprets this as signifying the presence of centrosomes on the walls of the basidia at the point at which the sterigmata are to form, and considers that the fibers are concerned in drawing the nuclei up into the spores which bud out on the tops of the former. I have observed in some cases in Hypochnus such fibers extending from the nuclei up into the developing sterigmata, but their origin I have not been able to determine. The fully formed spores contain a single nucleus and are oblong, and, as a rule, slightly flattened on one side.

I have also investigated the nuclear phenomena in a species of the Agarics, *Coprinus ephemerus.* Sections through the young fruit body reveal at once the conditions described by Maire. The stipe and pileus consist of large multinucleate cells with extremely numerous nuclei. A cross-section of a small group of cells from the stipe is shown in *fig. 12.* The cells in cross-section

are seen to be almost circular, and of extremely variable size. The entire cross-section of the stipe shows it to be made up of large cells, with very much smaller cells intermingled with them. The center of the stipe in these species is hollow, and the hollow space is bounded by a layer of these smaller cells. A longitudinal section of the stipe shows that the cells shown in *fig. 12* are immensely elongated and quite regularly parallel, and in turn are combined end to end to form parallel hyphae.

These sections show also that the cells contain very numerous nuclei, the number varying with their size. In very young carpophores the cells are quite rich in protoplasmic content, the protoplasm being largely aggregated in a central column running the length of the cell, in which most of the nuclei lie. As the cells elongate with the growth of the carpophore, they become proportionally poorer in content, and the nuclei are distributed more evenly.

The tissue of the pileus is also seen to be made up of large multinucleate cells. *Fig. 13* represents a group of cells from the peripheral region of the pileus, and shows four cells prolonged into blunt, spine-like processes, which project outward from the upper surface of the cap. The whole surface of the cap is covered with similar spines in this species. Between these spine-cells are the columnar outer cells of the pileus, forming a sort of epidermis, and beneath these again are mingled large and small cells. All of these different types of cells are multinucleate, but are not as large and do not contain as numerous nuclei as the stipe cells. They are also relatively poor in protoplasm, and contain a single large central vacuole, or numerous smaller ones.

It is doubtless the study of these cells of the vegetative part of the carpophore that has led to the conclusion of Strasburger, Wager, and others, that the vegetative bodies of the Basidiomycetes contain typically many nuclei. If we study the cells which are forming the gills of a carpophore of Coprinus, however, an entirely different condition of things is found. The gills originate as plates on the inner surface of the pileus as soon as it is differentiated around the upper end of the stipe. The separation

of the pileus from the stipe is, indeed, brought about, in part at least, by the development of these plates. The first formed gills are attached along their entire margin, for a time at least, to the surface of the stipe, and the cavities lined by the hymenial surfaces originate as thin, vertical, intercellular spaces, placed radially about the stipe, as is very well shown by transverse sections through the upper end of the young carpophore. These earliest formed gills later split off at their inner edges from the stipe as the pileus expands and gradually assumes the umbrella shape. The intercellular spaces, which are the interlamellar spaces, become wider with the growth of the pileus, and later formed gills arise in these spaces as further outgrowths from the under surface of the pileus. The study of the nuclei in these later formed gills is especially easy. The mature gill consists of two hymenial layers, with a vegetative supporting layer between them, the trama. In the young gill these parts are not sharply distinguished. It is formed simply as a ridge made up of hyphal branches, which grow radially inward and slightly downward. I am inclined to think that these hyphae branch just as do the hyphae in the hymenium of Hypochnus, in something like a cymose fashion, the apical cells being continually pushed to the side by branches produced from the cell beneath. The growth of the hyphae progresses radially inward and downward until the width of the mature gill is reached. The branches which are pushed out right and left terminate their growth almost immediately by the formation of basidia. These basidia intermingled with sterile cells, which are apparently their morphological equivalents, together make up the hymenial layers. In the young gill the hyphae are packed densely together throughout. As they grow older the central cells become separated by intercellular spaces in many cases, and thus form the looser tissue of the trama.

Since the axis of growth of the gill is radially inward and also downward, sections in an exactly transverse plane through the young carpophore do not show the method of growth as well as those which are slightly oblique. Such sections, inclined a few degrees to the long axis of the carpophore, lie in the axis

of growth of the hyphae of the gills and give the largest percentage of cells cut longitudinally in the young gill. This is of course true for the young gills on one side of the carpophore only, those on the opposite side, as will be readily understood, showing the hyphal cells cut more nearly transversely than in exactly transverse sections of the entire carpophore. *Fig. 11* shows the section of a very young gill taken from such an oblique section of a carpophore. The cells are nearly all cut longitudinally, and the method of their growth and branching is fairly well indicated. Still even here certain hyphae are seen to have turned up or down and out of the plane of the section, so that the axial hyphae of the base of the gill and the end cells are not connected to form a continuous hypha in the section.

The conspicuous fact here is that all the cells of the gill are binucleated. Following backward through the base of the gill, we should pass suddenly into tissue of the pileus exactly similar to that shown in the inner portion of *fig. 13*. It is not easy to trace a single hypha from the one tissue to the other; still there seems no doubt that the binucleated cells are the end ramifications of hyphae which farther back in the pileus and stipe are composed of multinucleated cells. In other words, as Maire's work shows, the ends of the hyphae which are to reproduce the organism by means of basidia and basidiospores have maintained the binucleated condition, while the mass of the hyphal cells, having only the functions of support and transportation of water, etc., to the reproductive cells to provide for, have become enlarged and multinucleated as a result of nuclear divisions unaccompanied by cell division. The reproductive series of cells, the *Keimbahn* of various authors, is thus sharply distinguished from the purely vegetative and somatic series by the number of nuclei which they contain respectively. In very early stages in the development of the carpophore the differentiation of the two types of cells is present and continues through its whole development. Whether the multinucleated cells increase in number by cell division, as do the binucleated, is not easy to

determine. It seems highly probable, however, that, like the internodal cells of Chara and Tradescantia, they may have lost the capacity to divide, the increase in number being entirely provided for by the division of the binucleate cells. The development of the carpophore, as pointed out by De Bary (4, p. 49) and others, is no doubt to be interpreted as consisting in the growth of hyphae, and it seems highly probable that the hymenium represents the end cells of the hyphal branches which are to be traced back through the pileus into the stipe, and so connected with the mycelial branch or branches from which the carpophore sprung. The growth would then be largely apical for these hyphae, the older cells lying in the pileus and stipe, and the youngest, latest formed, in the hymenium. That all the hyphae of the stipe have end cells in the hymenium is, of course, not necessarily assumed, though it is not improbable, in view of the wide expanse of the latter, that this is the case.

What the condition of the mycelial cells is in the species of Coprinus studied I have not been able to determine. Maire says that the mycelium of *Coprinus radiatus* is made up of uninucleated cells. The base of the stipe of *C. ephemerus* is surrounded by a mass of hyphae with multinucleated cells; whether these, however, represent the condition of the primitive mycelium from which the carpophore sprung I am by no means sure. It may well be that in the work of collecting and transporting material for the young carpophore the mycelial cells may have become enlarged and secondarily modified as to the number of their nuclei. There seems little doubt, however, that the condition in Hypochnus represents a very primitive condition for the Basidiomycetes, and that, as Maire maintains, all multinucleated cells in their vegetative bodies have been secondarily produced. How the condition of things in *C. radiatus* with its uninucleated mycelial cells is to be connected with that in Hypochnus is not plain. It is quite possible, of course, that the uninucleated condition represented in the basidiospore may be perpetuated for longer or shorter periods of development in different cases.

The subhymenial cells of *C. ephemerus* show very conspicuous disc- or saucer-shaped bodies arranged in pairs on opposite sides of their walls. These bodies stain deeply and are very numerous, lying on all sides of the hyphal cells wherever the walls of adjacent cells are in contact. *Fig. 14* shows two pairs of such bodies and their relative position with reference to the cell walls. Strasburger (15, p. 335) has described similar structures. They doubtless mark points where the walls are perforated in some fashion, thus establishing connection between adjacent cells. I have described such bodies for Pyronema (5), and also spherical granules which may have a similar significance.

Brefeld (1) has described the carpophore of *C. stercorarius* as arising from a single hypha of the vegetative mycelium. This hypha produces a richly developed system of branches which arrange themselves ultimately into the parts of the young carpophore. Vegetative growth of the mycelium and formation of the carpophore are thus seen in this case to be rather sharply separated, and it might well be that at this point the transition from uninucleated to binucleated cells is effected. However, no such differentiation of mycelial growth and carpophore formation exists in Hypochnus, whose mycelium is binucleated throughout in its mature condition. Maire says nothing as to the stage when the binucleated cells first appear in Coprinus. If his statement is true, that the mycelium of the latter plant is made up of uninucleated cells, it differs, as noted, from Hypochnus in this respect. Whether Hypochnus or Coprinus would represent the more primitive condition in this particular is not easily to be determined with certainty. Most mycologists, however, have agreed so far in regarding the Tomentelleae as primitive Basidiomycetes, and the Agarics as among the most specialized forms; and, in the absence of positive evidence to the contrary, this seems the most natural assumption. Still, it is quite possible that the Hypochnus type may be degenerate in certain particulars and may have lost a mycelium of uninucleated cells, such as Maire reports for *Coprinus radiatus*. Just where in this case the

binucleated condition would arise is not clear. There is little doubt, however, that the development of multinucleated cells in the group is correlated with the origin of large and complex carpophores, and that in lacking such cells Hypochnus represents a more primitive type.

Basing his conclusion on the resemblance of certain conidiophores of the Ascomycetes to the so-called protobasidia, Massee (11) seeks to connect the Basidiomycetes with the Ascomycetes. He believes that it is in asexual stages of the latter that the ancestors of the Basidiomycetes are to be found, accepting Brefeld's conclusion that the basidium is a conidiophore which has become determinate in the number of spores which it produces. Massee points out that the conidiophores of these asexual forms of the Ascomycetes conform very closely to the type of the Auricularia basidium. From the fact that about thirty species of the genus Stilbum and several species of the genus Tubercularia are known to be the asexual reproductive forms of species of the ascus-bearing genera Nectria and Sphaerostilbe, while other species of the former genera have never been found connected with ascus-bearing forms, Massee argues that these latter asexual forms are probably becoming independent and have lost the ascus-bearing stage permanently. The conidiophores of the Stilbum form of *Sphaerostilbe microspora* Cooke and Massee are already typical protobasidia. The same is true of *Tubercularia volutella*, whose so-called conidiophores are likewise protobasidia. The examination of a large number of forms of Stilbum and Tubercularia shows that a series of gradations from forms with typical protobasidia, *i. e.*, two or three short swollen fertile cells, to forms with unmodified conidiophores, *i. e.*, two or three long narrow fertile cells forming the end of the conidiophore, can be made out. As a rule, the conidiophores are found on forms which are still associated with an ascus-bearing stage. *Sphaerostilbe microspora*, however, is an exception to this rule. Isaria, many of whose forms are connected with Cordyceps, while others are, the author believes, independent species, shows also typical protobasidia in *I. pulcherrima* Berk and Broome; while

other species show the transition from protobasidium to conidiophore. Massee believes that Möller's protobasidiomycete *Pilacrella delectans* stands close to the Isaria forms. Massee concludes that the "protobasidiomycetes as a group are derived from the conidial phase in the life-cycle of ascigerous fungi; the evolution is effected by the disappearance of the ascigerous form of reproduction, whereby the conidial phase assumes the standard of a species; this change being contemporaneous with the gradual conversion of the so-called conidiophore to the typical basidium or spore-bearing organ." He does not accept Juel's proposition to transfer such forms as *Stilbum vulgare* Tode into the Protobasidiomycetes, holding that the transition stages are so characteristic that no hard and fast line can be drawn between the forms with protobasidia and those with conidiophores.

Massee follows Möller in denying that the true basidium with apical spores has been derived from the septate basidium. He believes that these non-septate basidia have been developed from conidia of the type seen in Matruchotia, Botrytis, Polyactis, and others, through the non-septate basidium with lateral spores of the type seen in Tulostoma. Brefeld's Auto- and Protobasidiomycetes are both derived from the Ascomycetes, but as separate and distinct offshoots. Whether each of the two groups is to be further regarded as polyphyletic and consisting of separate series derived respectively from the forms Stilbum, Isaria, etc., the author does not state.

In the light of the facts described by Maire and myself, as recorded above, all such conclusions as these of Massee are seen to be extremely uncertain. The typical binucleated condition of mycelial cells is as yet unknown in the Ascomycetes, and until a transition from the coenocytic to the binucleated condition has been discovered in the forms discussed by Massee, his argument can be regarded as of little value. The widespread occurrence of regularly binucleate cells in the Basidiomycetes, with the additional evidence that these cells reproduce by conjugate division and constitute the reproductive series (*Keimbahn*) in

each individual through at least a considerable part of its life-history, leading up to the formation of basidia, while no such binucleated cells are found in the Ascomycetes either in vegetative or ascogenous hyphae, shows that the two groups are widely separated phylogenetically. In the face of such differences, resemblance of outer form and method of spore-formation between conidiophores and basidia must be regarded as superficial and of uncertain value, and as wholly inadequate evidence for the conclusion Massee wishes to draw. On the other hand, it is quite clear that the binucleated condition in the hyphae of both groups stlll further strengthens the evidence for the relationship between the rusts and Basidiomycetes. The nuclear fusions occurring in the teleutospore and basidium are seen also to be directly comparable processes, and there is a strong presumption that in the Basidiomycetes, as in the Uredineae, this fusion is not between sister nuclei, but nuclei which by the process of conjugate division have remained distinct through long periods of vegetative growth. Maire affirms unequivocally the existence of conjugate division in all the forms he has studied.

It must not be assumed without further evidence that the rusts are primitive Basidiomycetes. Their parasitic habit is against this view, and the evidence from the resemblance of a sorus of Coleosporium to a true hymenium cannot be considered as very conclusive. Still, the binucleate condition of the hyphal cells suggests very strongly that rusts and Basidiomycetes must have arisen from some ancestral type characterized, at least in some stage of its development, by the possession of binucleate instead of uninucleated or multinucleated vegetative cells. How this binucleated condition arose originally is not at all clear. The view of Raciborski that the binucleated cells of the rust represent a prolonged vegetative stage interposed between two phases of a sexual act, namely the cell fusion and the nuclear fusion, is suggestive as a hypothesis, but it is nothing more.

The question as to the nature of the spermogonia and their relation to the aecidia of the rusts remains still unsettled, and

De Bary's view as to the relationship of the rusts and Ascomycetes must be given up.

Further, it is plain, in view of the above facts, that the processes of nuclear fusion in asci and basidia are, so far as the present evidence goes, entirely unrelated morphologically, and that ascus and basidium are not to be brought into any common category as oogonia, as is attempted by Dangeard. Neither the cells of the ascogenous hyphae nor the vegetative mycelial cells of the Ascomycetes are binucleated in any case so far investigated, and there is no suggestion of any close morphological resemblance between ascus and basidium. The significance of the fusion is not entirely clear in either case, but no light is thrown on this point by endeavoring to bring together such heterogeneous structures.

It is highly probable that the nuclei of the basidium, as of the teleutospore, are of widely separated ancestry. It is clear in the case of Pyronema, at least, that the nuclei which fuse in the ascus are not sister nuclei. Further than this the resemblance in this respect does not extend. The origin of the ascocarp in a sexual process is analogous to nothing which has so far been discovered in the Basidiomycetes. It may well be that both the origin and the physiological significance of the fusions in ascus and basidium are entirely distinct.

MADISON, WISCONSIN.

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EXPLANATION OF PLATE I.

All figures were drawn with the aid of the camera lucida, *figs. 1–4, 7*, and *9* with the Zeiss apoch. objective ap. 140, oc. 8, and *5, 6, 8*, and *14* with oc. 18.

Hypochnus subtilis.

FIG. 1. Hyphal cell showing two nuclei and the characteristic clamp connections.

FIG. 2. Young basidium and stalk cell, each with two nuclei.

FIG. 3. Basidium with two younger basidia budding out beneath it.

FIG. 4. Young basidium with two nuclei; stalk cell with young basidium budding out and containing a single nucleus.

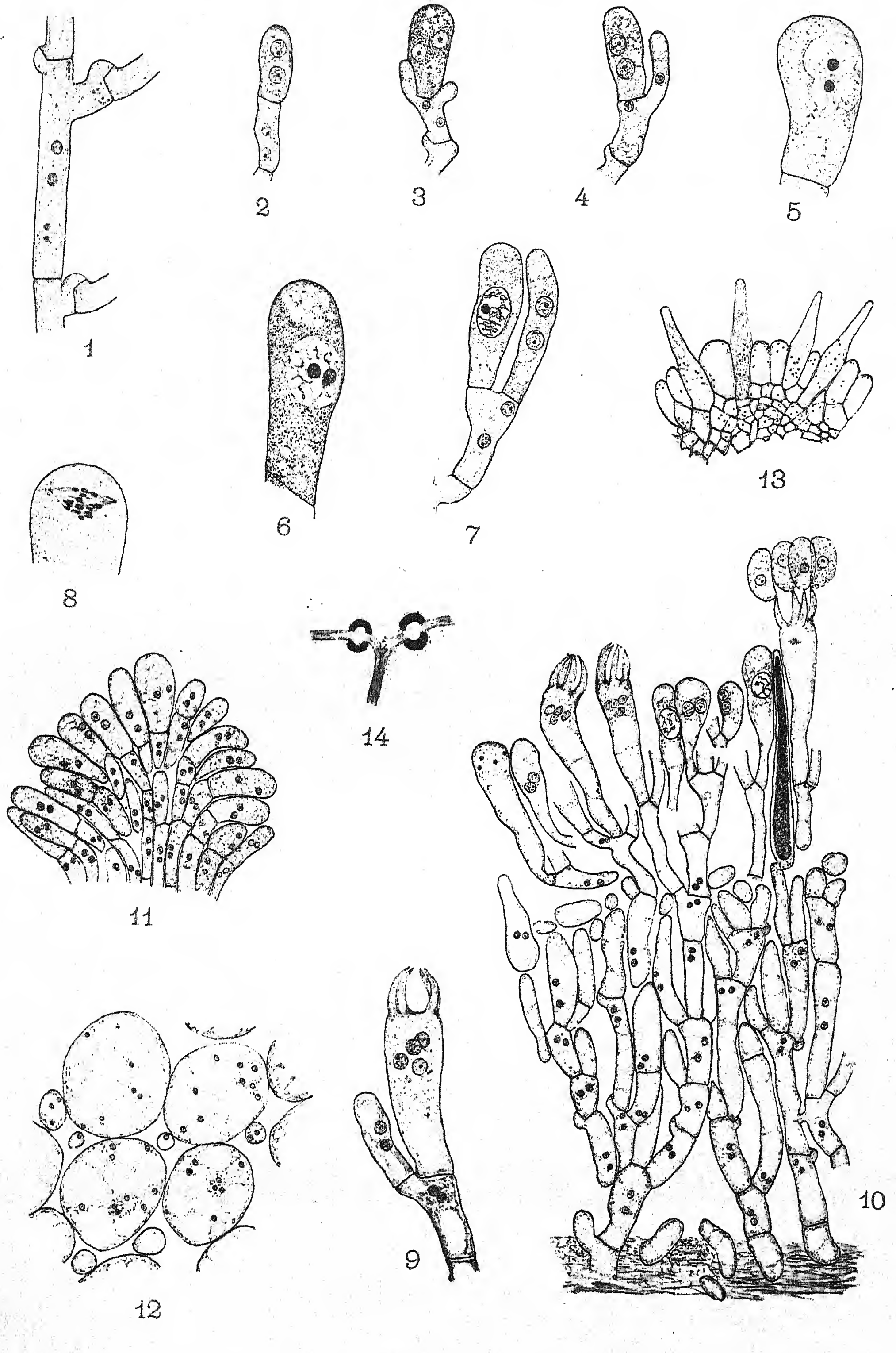
FIG. 5. Young basidium with its two nuclei fusing.

FIG. 6. Later stage in the fusion of the nuclei of the basidium.

FIG. 7. A pair of basidia in one of which nuclear fusion has taken place, while in the other it has not yet begun.

FIG. 8. First division of the nucleus of the basidium.

FIG. 9. Two basidia, one with four spore nuclei and sterigmata, and one with two nuclei before fusion.



HARPER on BINUCLEATE CELLS.

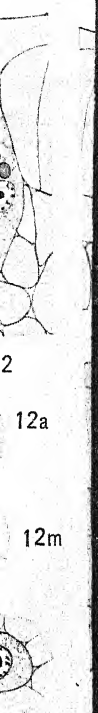

2
12a
12m

FIG. 10. Semi-diagrammatic section of the aerial portion: the upper layer is a young hymenium with basidia in various stages of development; to the right is a basidium with nearly ripe spores, each with a single nucleus; next to this basidium on the left is a young, only partly grown cystid, with very densely stained content; below the hymenium is a layer of vegetative tissue which has replaced a former hymenium; this is borne on three hyphal branches springing from the substratum below. × 800.

Coprinus ephemerus.

FIG. 11. Section of young gill made up of binucleate cells. × 800.

FIG. 12. Transverse section of a group of cells from near the upper end of the stipe of a very young fruit body. × 1000.

FIG. 13. Section of a bit of the peripheral tissue of the pileus, showing the columnar outer layer and four of the elongated papilla-cells.

FIG. 14. Parts of the walls of three sub-hymenial cells showing the pairs of bodies marking the position of intercellular pores.

ON THE TOXIC PROPERTIES OF SOME COPPER COMPOUNDS WITH SPECIAL REFERENCE TO BORDEAUX MIXTURE.

JUDSON F. CLARK.

(WITH SEVEN FIGURES)

WITHIN recent years copper has come to be the most valued agent in combating the ravages of plant diseases. Its importance from an economic standpoint has attracted to its study an unusually large number of investigators, and as a result there is a very extensive literature on the toxicology of copper compounds. The object of the present study was to determine more exactly the concentration of the various copper compounds required to inhibit germination or to kill the spores of a fairly large and quite representative selection of fungi grown under favorable conditions; to determine the effect of various media on the toxicology of copper; and to throw light on the toxicology of the Bordeaux mixture. I shall not attempt to review the literature of the subject, except to refer very briefly from time to time to a few studies which are of special interest in connection with points in the present study. Those especially interested will find work before 1896 quite carefully reviewed by Fairchild,[1] Swingle,[2] and Evans.[3] References and reviews of work since that time may be found in the various reviews. Hollrung's Jahresbericht[4] is especially useful in this connection.

[1] FAIRCHILD, D. G.: Bordeaux mixture as a fungicide. Bull. no. 6. Div. Veg. Path. U. S. Dept. Agric. 1894.

[2] SWINGLE, WALTER T.: Bordeaux mixture, its chemistry, physical properties, and toxic effects on fungi and algae. Bull. no. 9. Div. Veg. Phys. and Path. U. S. Dept. Agric. 1896.

[3] EVANS, WALTER H.: Copper sulphate and germination. Bull. no. 10. Div. Veg. Phys. and Path. U. S. Dept. Agric. 1896.

[4] HOLLRUNG, M.: Jahresbericht über die Neuerungen und Leistungen auf dem Gebiete des Pflanzenschutzes. Berlin. 1898 and 1899.

Copper occupies an intermediate position in regard to toxic value for the mold fungi.[5] It is surpassed more than a hundred-fold by mercuric chlorid, silver nitrate, and potassium chromate and bichromate. It is a little less toxic than nickel and a little more so than cobalt; distinctly more toxic than iron and the mineral acids; twelve times as toxic as zinc; and about eighty times as toxic as ethyl alcohol. Its great superiority as a fungicide lies in its cheapness, the tenacity with which its hydroxid, when properly prepared, adheres to the foliage of plants, and, as I shall show later, the solubility of its hydroxid in the presence of or by means of substances found alike in the cell sap of the host plant and of the parasite, but more especially the latter.

For a detailed description of the method of using the Van Tieghem cell for work of this kind the reader is referred to my article in a former issue of this journal.[6] I may add that the method has proved eminently satisfactory for various physiological and toxicological studies with pure cultures of fungi, yeasts, and bacteria.

Precautions for sterilizing were observed throughout the study, except with a few cultures of hymenomycetes. The spores used, of such fungi as can be normally matured in artificial culture, were taken from pure cultures frequently renewed to insure high vitality. Rhizoctonia and currant cane blight cultures were inoculated with mycelium taken from fresh pure cultures. With Hypholoma and Coprinus,[7] spores taken from plants growing under natural conditions were used. Naturally, every precaution was taken to avoid contamination, and on the whole very little difficulty was experienced on this account.

It is very important in any quantitative study of this kind to

[5] CLARK, J. F.: On the toxic effect of deleterious agents on the germination and development of certain filamentous fungi. Bot. Gaz. **28**: 289–327, 378–404. 1900.

[6] CLARK, J. F.: Bot. Gaz. **28**: 293. 1900.

[7] I beg to acknowledge my indebtedness to Dr. Margaret C. Ferguson, of Cornell University, who supplied me with the spores of Hypholoma and Coprinus, and to whose studies in the germination of the hymenomycetes I am indebted for the knowledge that they would be satisfactory for germination purposes in the media used.

have as nearly uniform a quantity of spores in the various cultures compared as possible. It is equally important to avoid bunches of spores in making the inoculation. Oversight in regard to either of these points is bound to result in more or less erratic and unreliable results. This is due to the fact that a toxic agent like copper, which effects the death of the spores by uniting with and precipitating the protoplasm, is itself also precipitated in the process and can no longer exert a deleterious influence. This precipitation process is naturally a strictly quantitative matter, and the amount of copper sufficient to sterilize a culture containing fifty spores may prove entirely inadequate were the number of spores quadrupled or even doubled. When bunches of spores are present the effect is still more mischievous. These bunches are relatively slowly penetrated by the copper-containing solution. Should the bunch contain air, as is usually the case, the process of penetration of the copper to the innermost spores is still further retarded. In the meantime such spores as are floating singly are quickly killed, precipitating their share of the copper, and it may be that long before the solution has fully penetrated the bunch it may have lost the greater part of its soluble copper and may be no longer able to kill the remaining spores. These may then germinate and grow almost as well as if no poison had been present. The difficulty was entirely overcome by soaking the spores for a longer or a shorter time in sterile distilled water with an occasional shaking. In some cases this soaking may be continued with advantage for days, in which case it is well to keep them at a low temperature to prevent germination. In all cases it was advisable to inoculate from a mixture of spores in water, a uniform inoculation being approximated in that way without great difficulty. It is equally important to have the culture drop of as uniform a size as possible. Absolute precision in these matters, however, is impossible, and the reader is reminded that slight variations in all cultures are to be expected. Indeed, as has been often suggested, spores taken from the same sporangium and placed in the same culture under absolutely similar conditions vary very

markedly in their capacity to resist poisons and other unfavorable conditions.

I would emphasize the importance of considering the *point of inhibition of germination* rather than the *death point* in consulting these results. The former can be determined with ease and absolute certainty by direct observation under the microscope, the latter only by transferring the spores to a fresh culture free as possible from the deleterious agent, and determining their success or failure to germinate under these conditions. The unavoidable source of error here is the transference of more or less of the copper compound with the spores. This quantity is doubtless often sufficient to prevent the germination of spores which although greatly reduced in vitality may be still alive. The general result of such transfers made at varying intervals from twenty-four hours to ten days indicated that if the germination of the spores be *inhibited* by a concentration of a copper salt, it was merely a question of time when they would be killed. Thus if a certain concentration inhibited the germination of a certain spore, possibly a solution of four times this concentration would fail to sterilize the culture in twenty-four hours, yet if left for some days the points of inhibition and death would finally coincide. The length of time necessary to bring this about would naturally vary with the varying specific characteristics of the spores of the different species.

The medium used for the cultures, the results of which are given in *fig. 1*, was a decoction of sugar beet. The root, sliced thin, in the proportion of 450^{gr} per liter, was heated in an autoclave for an hour at 120° C., under a pressure of one atmosphere. The decoction was then filtered and poured into flasks and thoroughly sterilized. This medium was selected for the comparative tests as giving the best results with the greatest number of the fungi used. The other vegetable decoctions were prepared in essentially the same manner.

Stock solutions of the various copper compounds were prepared by a responsible chemist. A *normal* solution of a copper compound means in this paper the number of grams of the salt

corresponding to the full molecular weight (*e.g.*, $CuSO_4.5H_2O$ = 249) dissolved in sufficient water to make one liter of solution; thus 0.01 *n* $CuSO_4$ equals a 0.249 per cent. concentration of the *crystallized* salt.

In the figures used to illustrate this paper the solid black bar indicates that the concentrations used were sufficiently strong to kill the spores within twenty-four hours. The square blocks alternating with the open spaces indicates that while the germination of the spores was inhibited, they still retained vitality enough to germinate several per cent. after twenty-four hours immersion. Four parallel lines indicate some germination but very poor development. Three parallel lines indicate fair but distinctly abnormal development, and two lines approximately normal germination and growth.

Fig. 1 shows in a condensed form the results of some four hundred cultures with fifteen fungi in a decoction of sugar beet to which had been added copper sulfate. A glance at the page will show that many of the fungi present a really remarkable similarity in resistance to copper. Twelve of the fifteen forms represent a range in lethal concentration of from 0.0099 *n* to 0.0168 *n*, or slightly less than 70 per cent. variation. This range of susceptibility may be modified by several important considerations, prominent among which is temperature. All, except Gloeosporium, were grown at 28° C., a little more or less. It is established that a fungus presents its greatest resistance to a deleterious agent, other things being equal, when cultivated at or near its optimum temperature for germination and mycelial development.[8] At a higher or lower temperature a smaller quantity of the agent results fatally. All the forms used, except *Gloeosporium malicorticus*, grew well at 28° C., but it is quite certain that some of them grow better at other temperatures. Inasmuch as the optimum temperatures for the different forms were unknown it was thought best to use a uniform

[8] CLARK, J. F.: On the toxic value of mercuric chlorid and its double salts. Jour. Phys. Chem. 5:289–316. 1901; also FLENDE: Ueber Creolin und seine Wirksamen Bestandteile. Arch. f. Hyg. 9:———. 1889.

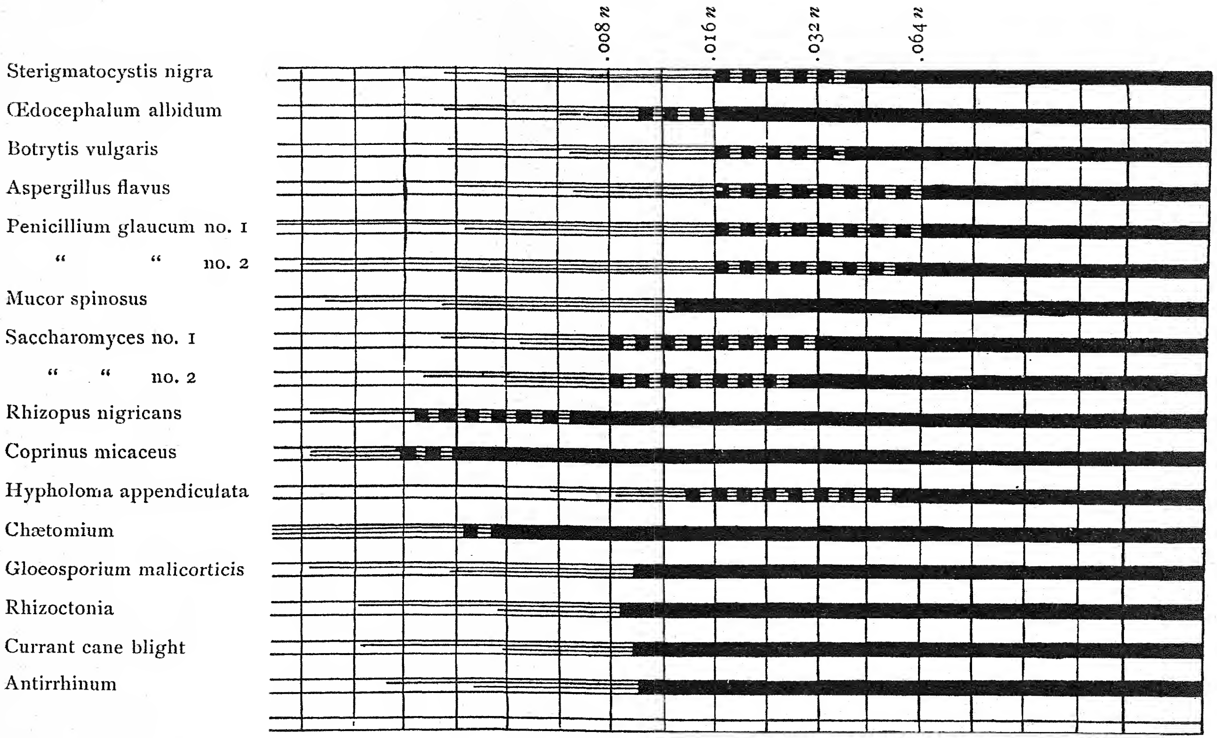


FIG. 1.

NOTE.—On account of the loss of the original drawings, while in the hands of the engravers, it is not possible to give *quantitative* values for this figure. The four values given are approximately correct. *Coprinus* was inhibited by .003 *n*.

temperature, except with Gloeosporium, which refuses to germinate at so high a temperature. It is also doubtless true that other *optimal* considerations have a similar effect in increasing the resistance of plants to unfavorable conditions. It should also be noted in studying these results that several of the forms were tested in media prepared at different times, and as sugar beets vary in composition the media would vary somewhat in nutritive properties, and therefore in toxicological properties also, when used as a solvent for a poison. Making due allowance for these considerations, however, it is perhaps remarkable that of a selection of fungi representing fairly well the natural groups and including typical saprophytic and parasitic forms, the great majority of them should be found to be killed under similar conditions by concentrations of copper of between 0.0099 n and 0.0168 n, and that the three forms which were found to be markedly more sensitive (Rhizopus, Coprinus, and Chaetomium) should be of such diverse relationships. The two species of yeasts proved to be equally resistant, although markedly different morphologically. The exact similarity of resistance was in this case very easily and prettily shown by growing both forms in the same culture drop. Such a test is applicable only where the forms are of similar properties as regards resistance to the agent, time of germination, and rapidity of growth. Two cultures of *Penicillium glaucum*, obtained from different sources and presenting slightly different habits of growth, also proved to be equally resistant.

The great variation between the two hymenomycetes is partly to be accounted for by the fact that the medium was very favorable for the development of Hypholoma, and only moderately suited for Coprinus. The similarity of resistance of the four parasitic forms (at bottom of figure) is quite striking. It will also be noted that they occupy an intermediate position. The most resistant forms will be seen to be the molds Aspergillus, Sterigmatocystis, Botrytis, and Penicillium.

Dr. Duggar has for some time been studying the broad field of food relation to toxicology in general. It has been

ascertained that fungi vary greatly in their resistance to deleterious agents, according to variations in the medium in which they are cultivated when submitted to the influence of the agent. His results have not yet been published, but the importance of this matter in any toxicological studies necessitates considerable reference to the subject in this study of the toxicology of copper.

The differences in resistance due to variations in the culture media may be due to two distinct causes: (1) All media influence the toxicology of electrolytes, and possibly other agents, by causing certain physical and chemical changes in the condition of the dissolved agent; (2) other things being equal, the more favorable the medium for germination and early mycelial development of a fungus, the more resistant that fungus will be to deleterious agents.

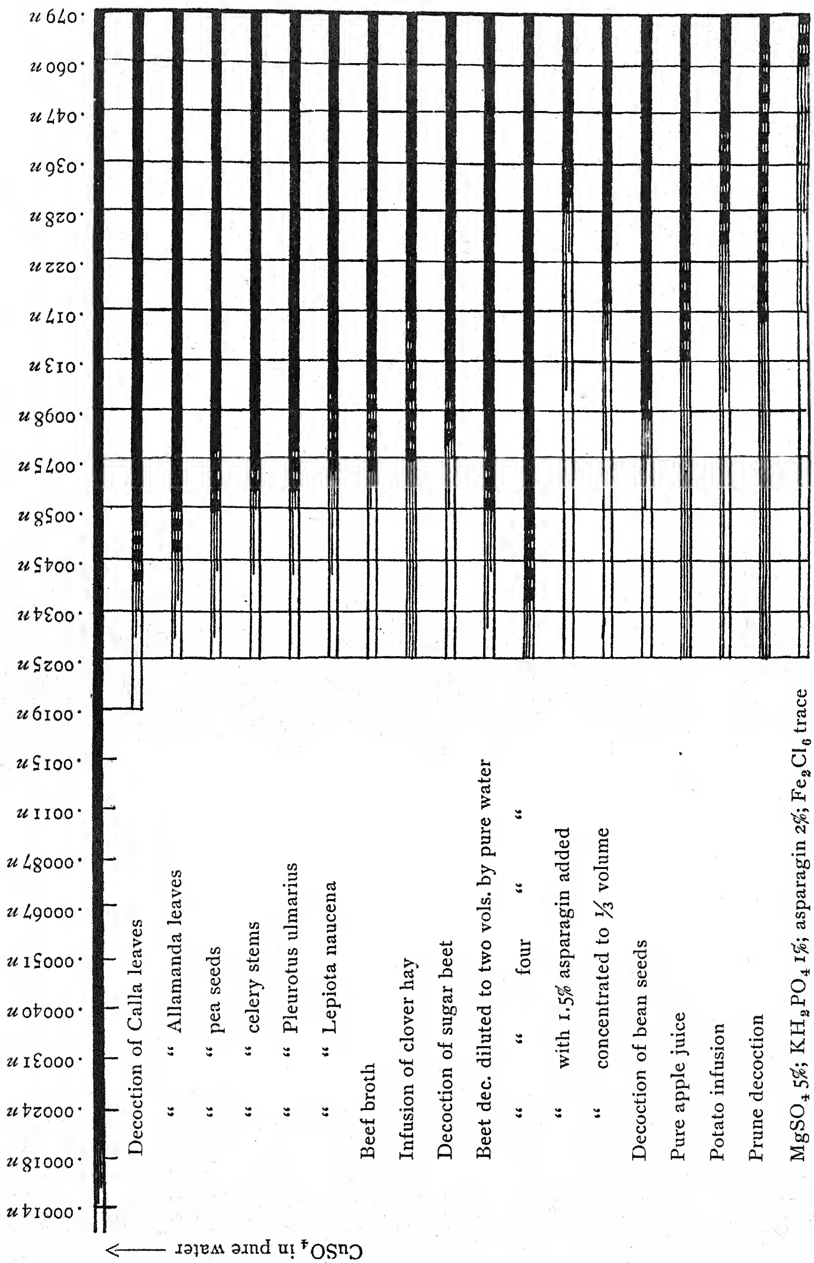
The simplest case of changed physical or chemical conditions would be the diluting of the solution of the copper salt with pure water. Here, with each decrease in concentration, we get less and less of the whole molecule, *e. g.*, $CuSO_4$, and more and more of its component ions, $^{+}Cu^{+}$ and $^{-}SO_4^{-}$, and the amount of change may be readily determined for any particular dilution. When the dilution is accomplished by adding an infusion or decoction of a vegetable or animal substance, however, a series of unknown reactions occurs, and even the amount of copper in the ionic form cannot be known. That these transformations have a very great influence on the toxic properties of the mixture is abundantly shown by the results represented graphically in *fig. 2*. A number of media tested caused precipitation of the copper, thereby rendering it harmless.[9] All such media were discarded and are not represented in the figure.

When spores are placed in a medium which does not admit of growth (*e. g.*, pure water) it is merely a question of time when these spores will be killed, if there be present a sufficient quantity of copper to precipitate the living proteids. It takes some

[9] COPELAND and KAHLENBERG: The influence of the presence of pure metals upon plants. Trans. Wis. Acad. 12: 454–474. 1900.

time, however, perhaps weeks, for all this copper to find its way into the spores. Should the medium be such as admitted growth, the production of protoplasm might easily offset its precipitation by the copper, and long before the copper could have its maximum effect the protoplasm would have increased manifold, and would require a corresponding increase in the concentration of copper to cause death. Thus it is that with every favoring influence the fungus can make a better fight for life.

The results given in *fig. 2*, with various media, and with copper in the form of the sulfate, are those with *Œdocephalum albidum.* The work repeated with *Rhizopus nigricans* gave essentially the same results. A single glance at the figure shows how much more toxic the copper proved to be when dissolved in pure water than when in any other medium, 0.0002 *n* being fatal in twenty-four hours. This is but one-fortieth of the concentration of copper required to give the same result in a decoction of sugar beet. When 1.5 per cent. asparagin was added to this beet infusion the toxic value of copper dissolved in pure water was to its value in the asparagin-beet medium as 142 : 1, and the comparison in the case of the medium compounded from asparagin and inorganic salts the ratio is 285 : 1. In this last case there was a slight precipitate noticed under the microscope, and it may be that some of the copper was precipitated by the phosphoric acid present. Exactly what proportion of this striking difference is to be assigned to the nutritive condition and what to chemical and physical transformations it is impossible to say. Inasmuch as the asparagin medium, while a good food for Œdocephalum, is not so good as beet decoction, we must concede that the remarkable decrease in toxic properties in the cases where asparagin is present is chiefly due to the physical and chemical changes. That these changes have a preponderating influence in the case of the beet decoction is also very probable. The experiment of diluting and concentrating the beet decoction seems to support this view. The values of the triple, the ordinary, the half, and the quarter strengths are not greatly different



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.00051n
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.00018n
.00014n
Decoction of Calla leaves
" Allamanda leaves
" pea seeds
" celery stems
" Pleurotus ulmarius
" Lepiota naucena
Beef broth
Infusion of clover hay
Decoction of sugar beet
Beet dec. diluted to two vols. by pure water
" " four "
" with 1.5% asparagin added
" concentrated to 1/3 volume
Decoction of bean seeds
Pure apple juice
Potato infusion
Prune decoction
MgSO$_4$ 5%; KH$_2$PO$_4$ 1%; asparagin 2%; Fe$_2$Cl$_6$ trace
CuSO$_4$ in pure water

FIG. 2.

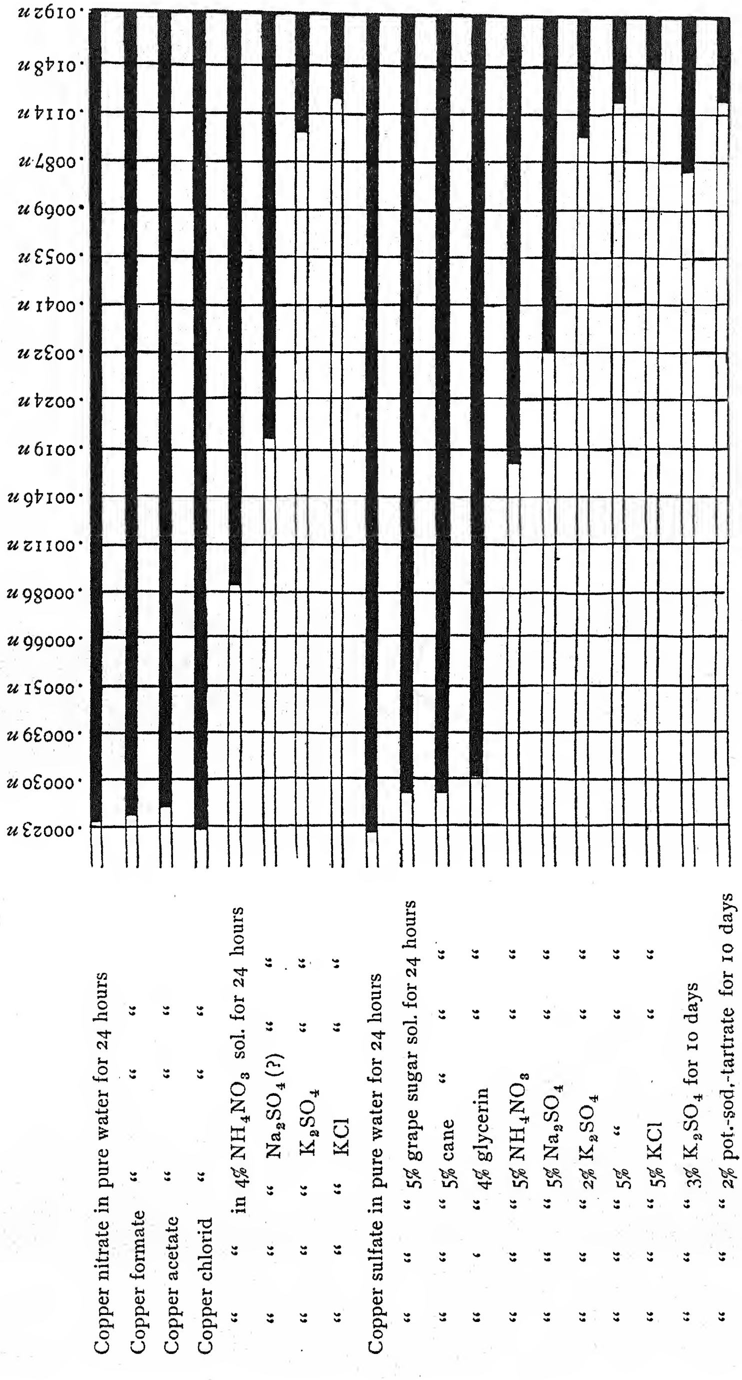
so far as stimulation of germination and early mycelial development is concerned. The same is true of the beet decoction to which the asparagin was added. Yet we have the following variation in the lethal concentrations:

Medium	Lethal concentration	Relative amount of Cu required to inhibit as compared with a pure water solution
Beet decoction, normal strength	0.0076 *n*	38 times
" " diluted to two volumes	0.0054 *n*	27 "
" " " " four "	0.0034 *n*	17 "
" " evaporated to ⅓ volume	0.0163 *n*	82 "
" " + 1.5 per cent. asparagin	0.0284 *n*	142 "

Were it wholly a matter of food relation we should expect the figures in the third column to be near 38 in each case. Were it wholly a matter of the chemical or physical transformation of the copper by the compounds present in the beet decoctions, we should expect a more proportionate decrease in the first three numbers of the third column, corresponding to the dilution of the medium by the added pure water. As already remarked, it is not possible to determine with any degree of precision the part played by any one factor from the data at hand; but it is evident that with different media great differences in the toxic value of the copper may be obtained, and that asparagin has the power of uniting with salts of copper in such a way as to reduce their toxic properties in a very extraordinary manner. It is of interest in this connection to note that mercuric chlorid is not similarly reduced in toxic properties by the presence of asparagin.[10]

Fig. 3 presents the results of some studies on the addition of certain compounds to pure water solutions of some copper salts. Here the results given are with Œdocephalum, and, as in *fig. 2*, the results were checked over with *Rhizopus nigricans*. In this diagram the vertical lines representing the variation in the concentration of copper present in the different cultures show an increase of 30 per cent. for each division over the last preceding

[10] Jour. Phys. Chem. 5 : 302. 1901.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.0019n
.00146n
.00112n
.00086n
.00066n
.00051n
.00039n
.00030n
.00023n
Copper nitrate in pure water for 24 hours
Copper formate " " " "
Copper acetate " " " "
Copper chlorid " " " "
" " in 4% NH_4NO_3 sol. for 24 hours
" " " Na_2SO_4 (?) " "
" " " K_2SO_4 " "
" " " KCl " "
Copper sulfate in pure water for 24 hours
" " 5% grape sugar sol. for 24 hours
" " 5% cane " " "
" " 4% glycerin " "
" " 5% NH_4NO_3 " "
" " 5% Na_2SO_4 " "
" " 2% K_2SO_4 " "
" " 5% " " "
" " 5% KCl " "
" " 3% K_2SO_4 for 10 days
" " 2% pot.-sod.-tartrate for 10 days

FIG. 3.

division passing to the right. It will be observed that the five copper salts, the nitrate, formate, acetate, chlorid, and sulfate, dissolved in pure water have approximately the same toxic value, the variation (0.00004 *n*) being within the limits of experimental error. These five salts are fatal to Œdocephalum in 0.00020–0.00024 *n* concentration in twenty-four hours. This is about a 0.005 per cent. solution of the crystallized salt, $CuSO_4.5H_2O$, or one part crystallized salt to 20,000 parts water.

The addition of glycerin, glucose, or cane sugar failed to cause any pronounced decrease in toxic properties. The addition of salts like K_2SO_4, KCl, etc., however, caused a very great reduction. One part $CuSO_4$ to 20,000 parts pure water is fatal to Œdocephalum in twenty-four hours. It requires sixty-one parts $CuSO_4$ to 20,000 parts of a 5 per cent. K_2SO_4 solution to have the same effect. That the lessening of the toxic value here was not due to a lessening of the rapidity of the penetration of the copper salt is shown by the last three lines of *fig. 3*, where the cultures after standing ten days showed a toxic value of less than one-fortieth that of the $CuSO_4$ in pure water. A test made by adding a small quantity of KCl to solutions of $CuCl_2$ gave an increase in the toxic value of the mixture. Further experimentation on this point is needed, but the indications are that here we have a similar phenomenon to that observed on the addition of chlorids to mercuric chlorid solutions,[11] small additions of a chlorid causing an increase, and larger amounts causing a decrease in toxic properties; the former probably through the formation of highly toxic $^-HgCl_4^-$ ions, and the latter through the formation of K_2HgCl_4 double salt molecules having a low toxic value. Copper reacts very similarly to mercury in respect to the formation of double salts with alkali chlorids.[12] These double salts would naturally be highly dissociated into metallic cations and the anion $^-CuCl_4^-$, and similar anions. That the ion $^-CuCl_4^-$ should have a high toxic value is very probable, being in harmony with all at present known regarding toxic

[11] CLARK, J. F.: Jour. Phys. Chem. 5: 289–316. 1900.

[12] REMSEN, IRA: Inorganic chemistry (advanced course) 589. 1892.

agents capable of uniting with more chlorin.[13] That the forcing back of the ionization of these double salts to the molecular form (*e. g.*, K_2CuCl_4) would result in a lowering of its toxic value seems more than probable, in view of what we know in the analogous case of the double salt K_2HgCl_4 already referred to, and furnishes a very reasonable hypothesis to account for the remarkable lowering of the toxic value of solutions of copper in pure water when a chlorid is added in excess. The decrease from the adding of sulfates, nitrates, etc. of the alkali bases is doubtless due to similar conditions.

Fig. 4 gives the results of a test of various soluble and insoluble copper compounds with three fungi grown in beet decoction. The letters *A*, *Œ*, and *B* refer to Aspergillus, Œdocephalum, and Botrytis respectively. Beet decoction has a very marked power of dissolving copper even in the metallic state, hence it was possible to test "insoluble" copper compounds, such as Paris green, copper hydroxid (the form in which the copper is found in Bordeaux mixture), etc. This power of dissolving copper is a property of almost all decoctions of vegetable or animal substances, some possessing it in a much higher degree than others.

Fig. 4 shows that copper, gram for gram, has much the same value toxicologically when added to a beet decoction, no matter what form of copper salt is used. The apparent exceptions to this are are to be accounted for by the effect of the other atoms and groups added. Thus the chromate salt which proved to be by far the most toxic compound of copper tested owes its high toxic value to the deadly chromium contained.[14] The *eau céleste* and the ammoniacal solution of copper carbonate are particularly fatal to Œdocephalum and Botrytis on account of the basic alkalis present.[15] Œdocephalum is apparently very sensitive to compounds containing arsenic. Perhaps it is especially sensitive to this element, but so far as I know the point has not been tested. That the green arsenoid should be more fatal

[13] DAVENPORT, C. B.: Experimental morphology 8. 1897.

[14] CLARK, J. F.: Bot. Gaz. **28**: 390, 396. 1899. [15] *Ibid.* **28**: 380–382. 1899.

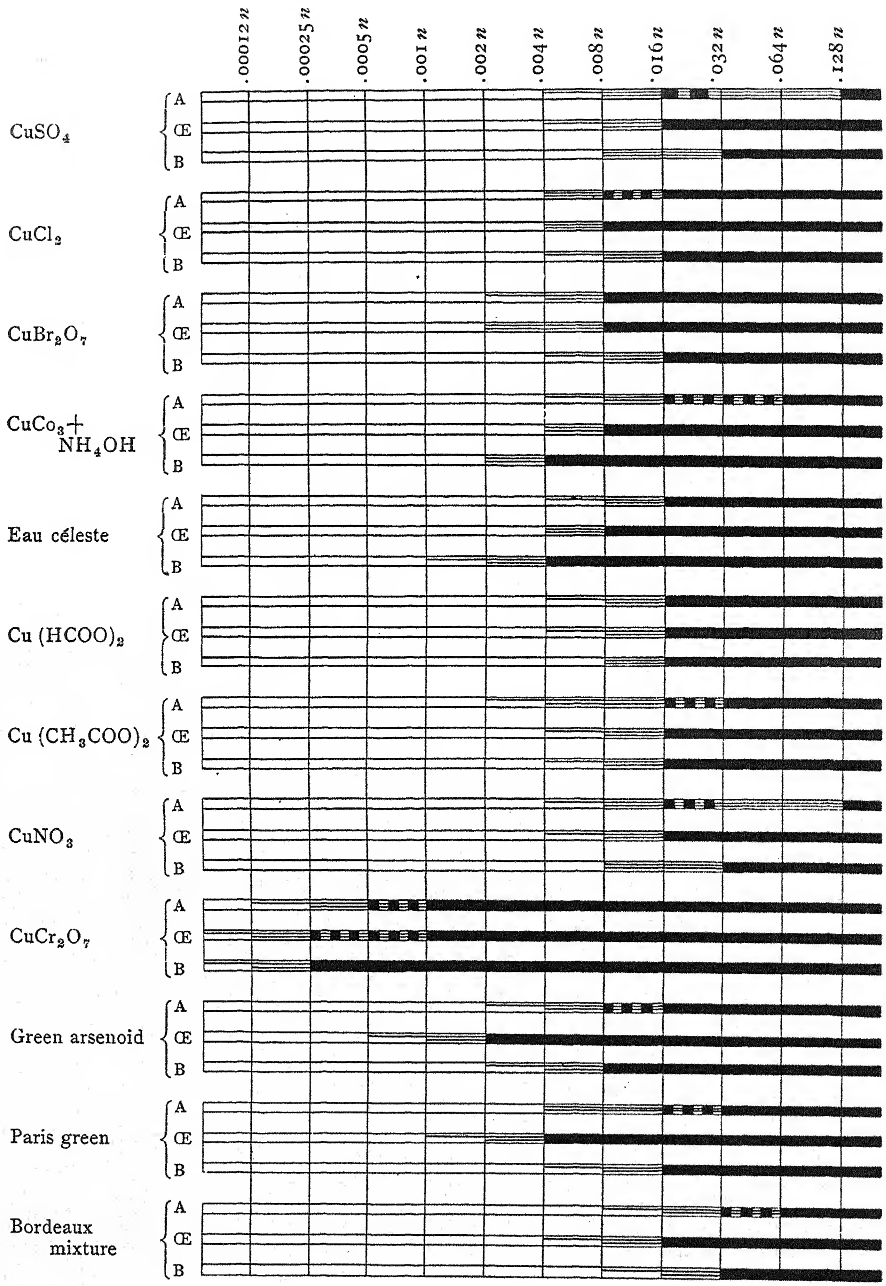
.00012 n
.00025 n
.0005 n
.001 n
.002 n
.004 n
.008 n
.016 n
.032 n
.064 n
.128 n
$CuSO_4$
$CuCl_2$
$CuBr_2O_7$
$CuCo_3 +$ NH_4OH
Eau céleste
Cu $(HCOO)_2$
Cu $(CH_3COO)_2$
$CuNO_3$
$CuCr_2O_7$
Green arsenoid
Paris green
Bordeaux mixture
A
Œ
B

FIG. 4.

than the Paris green was to be expected, inasmuch as it showed on analysis 8.3 per cent. soluble As_2O_3 as compared with 1.8 per cent. soluble in the sample of Paris green. That the ammoniacal solution of $CuCO_3$ is a more effective fungicide than Bordeaux mixture for the amount of copper used does not follow from the showing made in this figure. These tests were made in closed cells where the excess of ammonia was indefinitely retained, whereas under orchard conditions this evaporates in a few hours at most, and exerts practically no fungicidal value.

It would be beyond the province of the present paper to give a detailed account of my experiments on the toxicology of the Bordeaux mixture. These are of greater interest to horticulturists than to botanists. I shall mention briefly, however, the more important experiments and state the conclusions arrived at from this study.

Just how the insoluble copper hydroxid of the Bordeaux mixture sprayed on leaves has protected them so thoroughly from the ravages of parasites has long been a mystery to the chemist and physiologist alike. Various hypotheses have been propounded from time to time, but up to the present no satisfactory explanation has been given. A very careful review of the current hypothesis may be found in Swingle's paper.[16] His own suggestion that it might be possible that the fungi themselves, by secretions or excretions, might be able to aid in the solution of the copper has proved a happy one. As already mentioned, most animal and vegetable decoctions have a greater or less power of dissolving insoluble copper compounds.

This power is particularly noticeable in the fungi. An infusion of *Agaricus campestris*, and infusions and decoctions of various parasitic fungi, dissolve copper hydroxid very quickly and in sufficient quantity to inhibit the germination of any fungus tested. Spores of various fungi placed in a mixture of $Cu(OH)_2$ and water were killed in a short time, while other spores of the same species, placed in similar mixtures of $Fe(OH)_2$

[16] SWINGLE, W. T.: Bordeaux mixture. Bull. no. 9. Div. Veg. Phys. and Path. U. S. Dept. Agric. 1896.

and $Al(OH)_3$ retained their vitality unimpaired for weeks. The death of these spores was not due to the presence of any soluble copper, for no copper could be detected in the filtrate by the most delicate chemical tests before the spores were added. Traces of copper were found some time after the addition of the spores (if added in considerable quantity) showing that they dissolve more of the $Cu(OH)_2$ than was required to kill them. The rapidity with which fungus spores are thus killed naturally varies with the character of the contents and coverings of the spores. It is very quickly accomplished in thin-walled spores, such as Rhizopus and Œdocephalum, but is very slowly accomplished in forms like Aspergillus and Penicillium, whose coats present great resistance to the entrance of poisons and the excretion of copper-dissolving compounds. As an example of such resistance to entrance, see experiments with Aspergillus in solutions of nickel sulfate,[17] in which 0.03 *n* inhibited germination, but immersion in a normal solution (containing over 13 per cent. $NiSO_4$) for 48 hours at 28° C. failed to kill the spores. The same form resists immersion in double normal $ZnSO_4$ (27 per cent. anhydrous $ZnSO_4$) under similar conditions.

The host plant, too, is active in dissolving the $Cu(OH)_2$. A peach tree was sprayed with Bordeaux mixture which contained an excess of lime, as is ordinarily the case. Following this, the tree was sprayed several times during the day with enough pure water to have an effect resembling dew. The following day water collected from the leaves, filtered and evaporated to small volume, showed just a slight copper reaction. Several small leafy branches were then removed and placed in a large beaker of distilled water, without injury to any of the parts. After soaking for some hours these were removed and the solution filtered, evaporated to small volume, and tested for copper. A marked reaction was secured, indicating the presence of considerable copper in solution. The epidermis of leaves, although protected by a cuticle, is well known to be more or less permeable to the dissolved substances occurring in the cell sap, particularly along

[17] CLARK J. F.: Bot. Gaz. **28**: 392. 1899.

the union of the epidermal cells.[18] When the dew is on the leaf we have two solutions—the dew drop without and the cell sap within—separated by a more or less permeable membrane. The result of these conditions must result in the exosmosis of at least some of the contents of the cell sap, which coming in contact with the copper hydroxid adhering to the leaf surface causes more or less of it to pass into solution. An important point in this connection is that the solution of the copper, whether effected by the host or the fungus spore itself, is possible in the presence of an excess of lime. This excess is apparently somewhat detrimental to the solvent action on the copper, and in this way doubtless serves a very valuable purpose in preventing a too rapid solution. It also protects the $Cu(OH)_2$ from the solvent action of the ammonia, nitrites, and nitrates of the atmosphere. According to Millardet and Gayon's[19] experiments, the amount of lime ordinarily used in Bordeaux mixture is sufficient to protect the copper absolutely from solution for eighteen days under ordinary atmospheric conditions. This ought to have been sufficient to have set aside the hypothesis which accounted for the solution of the copper of the Bordeaux mixture by atmospheric conditions, for all experiments go to show that the Bordeaux mixture is effective from the day it is applied. So much in brief review of some of the experiments that have led me to the following conclusions regarding the toxicology of this invaluable fungicide:

1. The solution of that part of the $Cu(OH)_2$ of Bordeaux mixture which under orchard conditions *is of fungicidal value, is chiefly accomplished by the solvent action of the fungus spores themselves*, for they have power to dissolve sufficient copper to kill themselves.

2. The amount of copper necessary for the destruction of the spores of parasitic fungi is probably not more than one part of soluble metallic copper to 80,000 parts water (dew).

[18] BÜSGEN: Ueber einige Eigenschaften der Keimlinge parasitischer Pilze. Bot. Zeit. 57:67. 1893.

[19] MILLARDET et GAYON: Les divers procédé de traitements du mildiou par les composés cuivreux. Jour. des Agr. Prat. 1:701–702. 1887.

3. The host plant has a greater or less power of dissolving the $Cu(OH)_2$ deposited on its leaves.

This solution of the copper by the host plant may or may not be advantageous in protecting it from attack, as injurious spores may or may not chance to be present at the point where solution has taken place. To this factor, however, must be attributed the injury frequently observed with certain plants (*e.g.*, Japanese plums, peach, etc.) when sprayed with Bordeaux. The amount of injury done to a given species will depend on the following considerations, provided always that carefully prepared Bordeaux mixture has been used:

1. The *specific susceptibility* of the protoplasm of the plant to poisoning by copper.

2. The *solvent properties* of the cell sap on copper hydroxid.

3. The *permeability of the epidermis or cuticle*[20] to these cell contents when the conditions are favorable for their exosmosis, and for the entrance of the copper after its solution is effected.

4. Weather conditions following spraying, particularly conditions as regards moisture (dew, etc.), providing the conditions for the exosmosis of some of the contents of the cells of the leaf.

To these might be added, perhaps, climatic conditions which, through modifications of structure, of specific resistance, or of the character of the cell sap, may cause a plant to be more or less resistant to treatment with Bordeaux mixture, according to the locality where it is grown. The very injurious influence of Bordeaux mixture on blossoms[21] is to be explained in an entirely similiar way. Here the protection of the cells by cutinization is almost or entirely wanting, and it is very probable that the rich

[20] Dr. W. C. Sturgis (Rep. Conn. Agric. Exper. Sta. 219–254. 1900) has done some very careful work on the effect of Bordeaux mixture on peach foliage. In his study for a cause of the extreme susceptibility which he found in his peach trees, he has unfortunately overlooked the possibility of specific sensitiveness to copper poisoning of the protoplasm; and in the study of the structure of leaves the study of the cutinization of the epidermis has been omitted. It is hardly possible that the aeration of the spongy parenchyma can be a factor in the case.

[21] BEACH, S. A., and BAILEY, L. H.: Fruit-setting of sprayed blossoms. Bull. 196. N. Y. Agric. Exper. Sta. 1900.

contents of pollen grains and the cells of the stigma have an unusually solvent action on the copper hydroxid.

Swingle's proposition that the copper might be effective in preventing the attack of parasites through negative chemotactic action induced me to make a number of experiments on this point. A number of fungi were used to a greater or less extent,

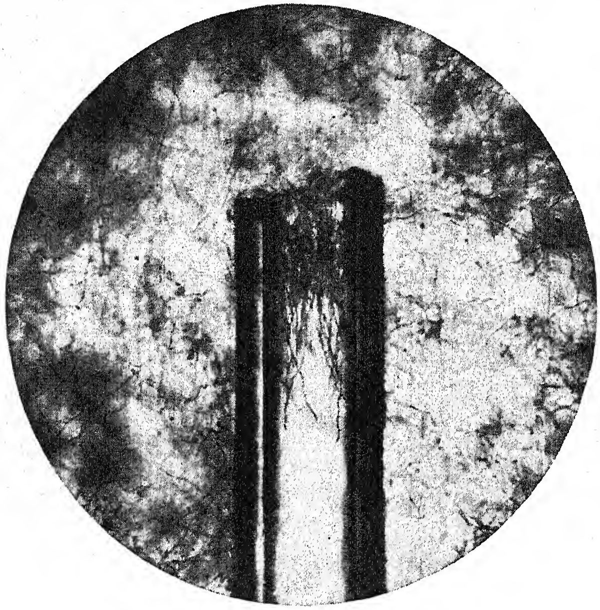

FIG. 5.

but Rhizopus proved the most satisfactory, inasmuch as it usually germinates with a single germ tube and grows rapidly with a minimum of branching.

The well-known method of Pfeffer was first employed. Capillary tubes closed at one end were filled with solutions of copper of varying strengths. Hanging drop cultures of the fungi were prepared in weak agars of varying consistence. Into these hanging drop cultures were introduced the open ends of the copper-containing capillary tubes. These tubes were introduced at different stages of germination. The uniform result of

these preparations was that the hyphae near the mouth of the tube grew into the solution of copper, and continued to grow directly inwards until they reached a concentration sufficient to kill them (*fig. 5*). This was found to be the case with copper, cobalt, nickel, zinc, etc., and *also when the capillary tube contained pure water.*

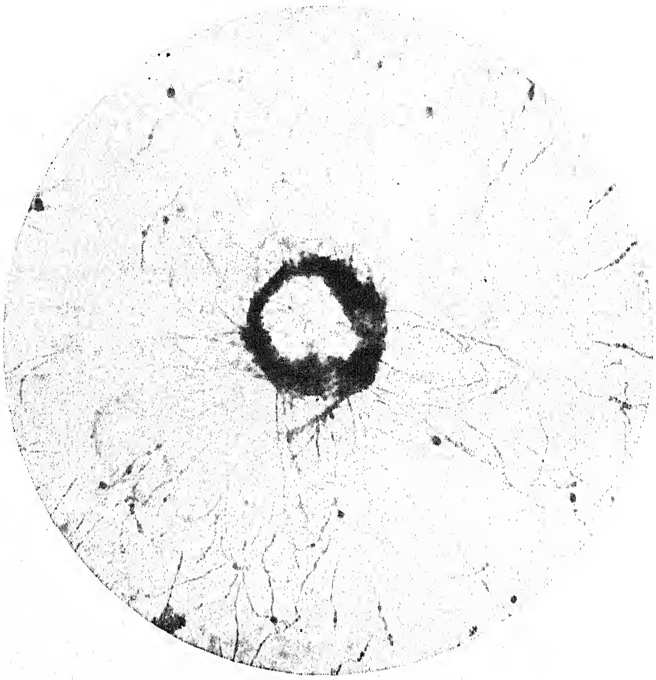

FIG. 6.

Miyoshi's[22] method of injecting leaves with solutions by placing them in the solutions under an air pump and exhausting was next tried. After the injection of the leaves they were washed under the faucet and spores of Rhizopus were sown on the lower surface. The preparation was then placed in a moist chamber in an incubator at 28° C. The germ tubes near stomata curved towards and grew directly into them in a manner quite similar to what Miyoshi found to be the case when the leaf was

[22] MIYOSHI, M.: Ueber Chemotropismus der Pilze. Bot. Zeit. 52: 1–27. 1894.

injected with food solutions. In many cases upwards of thirty germ tubes were counted growing into a single stoma. On injecting similar leaves with pure water, however, I got a similar result. The leaves used were chiefly from *Tradescantia discolor.* The concentrations of copper, cobalt, etc., injected ranged from 0.01 to 0.005 *n*.

I then tried Miyoshi's method of using perforated mica plates with layers of media between. Spores were sown in every conceivable way: in upper, middle, and lower layers; in nutrient and non-nutrient media; and in media containing copper. The uniform result of these tests was that the germ tubes near the perforations grew towards the opening *if it communicated with a layer of media in which no spores had been placed.* The presence or absence of copper was not found to have any influence on the *direction* of growth. The hyphae grew towards, and in cases where the concentration of copper was not too great, grew through the perforation into the copper-containing medium. *Fig. 6* illustrates such a case. The spores of Rhizopus were sown in a rich nutrient agar. Upon germination they immediately turned towards a perforation in the mica plate which communicated with a non-nutrient agar impregnated with 0.005 *n* $CuSO_4$.

Finally, I prepared a series of cultures in large Van Tieghem cells 5^{cm} in diameter. The nutrient agar in which the spores were placed occupied the part marked *a* in *fig. 7*. The portions of agar marked *b b* were prepared from nutrient or non-nutrien agar to which varying concentrations of copper had been added The portions *c c* are checks, being duplicates of *b b* without the copper. The inoculation was made by placing a few spores of Rhizopus at the center of *a*. The cultures were then placed in the incubator at 28° C. until the fungus had made considerable growth. The cells were then opened and *b b* and *c c* were pushed towards *a* until in slight contact and occupying the positions *b′b′* and *c′c′*. More or less of the Cu in solution in *b′* and *b′* would then pass into *a*, and if the fungus was either attracted or repelled by the Cu it would be readily determined by watching

the behavior of the hyphae as they grew down *a* towards the extremities *d d* between the copper-containing portion *b′* and the check preparation *c′*. The hyphae did curve towards *b′* and *b′*, but also towards *c′* and *c′*, and the *larger* the portions *b′* or *c′*, the more strongly they curved towards them. This curving took place even when *b* and *c* contained no nutrient substance, the hyphae growing from the nutrient portion *a* into a nonnutrient medium. Cultures on this plan were repeated many times and varied in many ways, *e. g.*, varying the consistence of the agar, the nutrients used, the concentration of copper, etc.

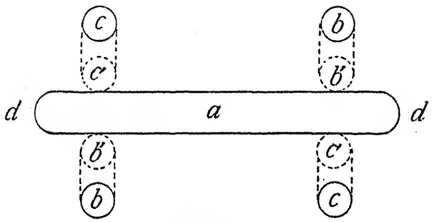

FIG. 7.

My interpretation of these results is that Rhizopus is markedly negatively chemotactic to some secretion of its own mycelium, and this negative chemotropism is much greater than any positive chemotropism it may have for food substances or oxygen. This method then, which seems to be satisfactory, has failed to show that Rhizopus has positive or negative chemotropism towards copper or allied metals. These cultures were used to a less extent with several other saprophytic and two parasitic forms, with the same result in regard to chemotropism towards copper. A large number of photomicrographs and drawings with camera lucida were made, but those reproduced in *figs. 5* and *6* are as instructive as any.

BOTANICAL LABORATORY,
CORNELL UNIVERSITY.

CLADOCHYTRIUM ALISMATIS.

CONTRIBUTIONS FROM THE CRYPTOGAMIC LABORATORY OF HARVARD UNIVERSITY. XLIX.

G. P. CLINTON.

(WITH PLATES II–IV)

WHILE collecting at Glacialis pond, Cambridge, Mass., in October 1900, the writer found *Cladochytrium Alismatis* Büsg. on *Alisma Plantago* L. Although the season was so far advanced for this plant that all of the leaves were dead and in many cases broken off, still enough infected ones were obtained to show that the fungus was not uncommon in that locality last year. The discovery of the fungus is especially interesting since this is the first time it has been found in America, and also because the study of it revealed the possession of a peculiar temporary sporangial stage that it was not known to possess.

This Cladochytrium occurs on the leaf blades, petioles, and peduncles, forming lead-colored, generally subcircular sori 1–2^{mm} in diameter. These are generally distinct from one another, and on the woody tissues are apt to have more of an elongated shape. In the leaf blades the so-called spores, or resting sporangia, occupy the cells between the two layers of epidermis, producing a slight pustule which in the green leaves, as shown by *exsiccati* specimens, is surrounded by a rather inconspicuous discolored area. While the sori are long covered by the epidermis, in the dead leaves this eventually breaks open and the sporangia become scattered, thus leaving small circular holes in the parenchyma and pits in the woody tissues.

Although a temporary mycelium is developed in this genus, the fungus in this case was so far matured when discovered that no sign of it could be made out. From one to three or four sporangia were found in the parenchymal cells of the leaf blade (*fig. 33*), while in the more elongated cells of the peduncle there

were often six or more arranged uniserially (*fig. 34*). The sporangia are oval to spherical, with sides sometimes slightly flattened, and vary from 25–45 μ in longest diameter. The cell wall is reddish-brown and rather thick, the exospore being smooth and prominent, and the endospore thin and hyaline. Attached to the exospore are often the remains of the plant cell. The contents of the sporangium consist of a more or less granular band of protoplasm adhering to the cell wall and a large central oil drop. In sporangia kept indoors for some weeks there seems to be a space between the oil drop and the protoplasmic band, though when young this is entirely occupied by the protoplasm in its more fluid condition.

Fischer (7) states that the sporangia of this fungus have never been germinated. The writer was successful in germinating the sporangia abundantly in the many trials made. When first collected a few sporangia would germinate in each trial, after being two or three days in a drop of water; but gradually it took longer and fewer germinated, until after they had been six to eight weeks indoors they ceased to germinate altogether. It was found, however, that if the infected leaves were placed in a small wire cage packed in damp moss and kept in a cool place the sporangia gradually assumed a condition favorable for germination when they were placed in a drop of water. Sporangia thus kept, even at the end of several months, germinated quite abundantly. Material, however, that had been placed outdoors at the same time in stoppered bottles and exposed to the cold of winter, but not to moisture, did not germinate very well. Most of the germinations were made in a drop of water in Van Tieghem cells at the ordinary room temperature.

The germination is similar to that given by Büsgen (5) for *Cladochytrium Butomi*. By osmotic action the sporangium becomes swollen until the exospore is broken open. This rupture is regular, a lid being split off in a circumscissile manner from about a third of the sporangium, which begins to crack at one side (*fig. 34*). The endospore meantime protrudes and eventually carries the lid at its top (*fig. 38*), or rarely bends it back as if on a hinge.

The exospore breaks open in so regular a manner that it indicates some definite line of dehiscence, though no such appearance was made out on the mature sporangia before germination. In the meantime there is a change in the contents. So far as could be determined, the large central oil drop is gradually eaten away from its circumference inward until it disappears, or is really broken up into a large number of very small drops scattered through the protoplasm. This latter is now seen to be very faintly divided into areas, showing the formation of the zoospores, in which the small oil drops frequently appear to be arranged more or less peripherally (*fig. 38*). These small oil drops gradually unite in each area to form the final large oil drop of each zoospore (*fig. 39*), and it is these oil drops more than any separating lines that indicate the number and position of the mature zoospores. While this has been going on, the papilla of dehiscence has been forming, though the sporangium is not always placed so that it can be seen. The papilla is best made out when examined in optical section at one side of the sporangium (*fig. 39*). It is usually a somewhat protruding area developed in the wall of the exposed endospore, and begins its dehiscence by the swelling of the cell wall which gradually extends inward as a hyaline area, due to the gelatinization of the wall. In some cases shortly before dehiscence this area seemed to be somewhat pitted, as is mentioned by Büsgen, perhaps allowing a greater flow of water into the sporangium, forming the extended hyaline space in this vicinity. In one sporangium, carefully watched, there could be seen no further change at this point, the hyaline space now having greatly extended inward, until there was a sudden movement of the mass of zoospores, and one coming out into this space darted toward the somewhat distended area in the endospore, and, apparently forcing its way through, escaped, and was followed, one by one by the others, about a hundred, until all had gone. This place of escape usually shows a polygonal opening with a few cracks extending from the angles (*fig. 37*).

The zoospores are somewhat variable in size and vary from

ellipsoidal to spherical in shape. In most cases, however, while active they have the ellipsoidal form. Each one is provided with a prominent oil globule, usually protruding somewhat at one side, and a posterior cilium, three or four times its length, situated at the end nearer the oil globule. A denser mass of protoplasm can be seen on the other side of the oil drop (*fig. 40*). The zoospores are active from the first, moving with a swift-gliding motion for a short distance and then coming to rest, but soon moving on again, so that it is rather difficult to follow one for any length of time. With a high power the cilium can be made out readily when the zoospore is at rest. The movement is always in the direction of the end away from the cilium. The zoospores sometimes apparently remain active for twenty-four hours, and possibly under favorable conditions even longer. Sooner or later, however, they gradually grow more sluggish in their movements, eventually becoming rounded and losing their cilium (*fig. 42*). At this period they often exhibit slight amoeboid movements. They finally come completely to rest and the oil drop gradually disappears. Unless favorably situated they go to pieces, the process in the last stages being assisted by bacteria. A peculiar feature observed at this time was the appearance of a vacuole in which could be seen one or two irregular somewhat elongated protoplasmic bodies that kept up a constant vibration which did not seem to be merely Brownian motion (*fig. 43*).

After it was found that the resting sporangia of this fungus would germinate, it was thought desirable to see if further information concerning its life history could be made out. Accordingly some seeds of *Alisma Plantago* L. were gathered and germinated. This germination took place very slowly, requiring a preliminary soaking of the seeds in water for three or four weeks. The young seedlings first send out a filiform cotyledon, and the succeeding leaves for some time are merely phyllodia adapted for aquatic existence. These have chlorophyllous epidermal cells, but are so thin that they can be watched easily even under high powers of the microscope. In

some of the experiments the plants were allowed to take root in soil covered with water, and the leaves removed as desired for examination. It was found, however, that even a piece of a leaf would remain fresh and active in a drop of water in a Van Tieghem cell for several days, and thus could be watched directly. The best results were obtained with young seedlings whose roots were placed in one of the arms of a Ward cell partly filled with a nutrient solution, and the first grass-like leaf was held up by a little cotton support so that it adhered to the cover glass containing a drop of water and the sporangia.

This species of Cladochytrium is placed by some botanists under the genus Physoderma, because it was not known to have a temporary sporangium. Our experiments were somewhat surprising, since they showed not only that such a stage existed, but that it was of a quite peculiar type. When this was first seen its relation to Cladochytrium was not suspected, but when it became evident that the two were connected, a large number of culture experiments were made in order to remove all doubt. The result was that this temporary stage appeared in every case where the resting sporangia germinated in water containing the young Alisma, and failed to appear in every case where the sporangia did not germinate and in the checks, both where nothing was placed with the young Alisma and where merely a piece of the old Alisma leaf which contained no sporangia was added.

As the zoospores are usually quite active for some time, it was impossible to follow a single one from the time of its exit from the sporangium until it came to rest. It was not difficult, however, when they began to grow sluggish in their movements, to find them settling down on the Alisma leaf and to watch them in their subsequent development, so that there was no doubt as to their identity. They almost always fix themselves on the epidermis just above the wall dividing two cells (*figs. 1–4*). Many do not succeed in penetrating the leaf, as the majority of those that were continuously observed during this stage failed to effect an entrance. In such cases the zoospores are sooner or

later destroyed. In other cases, however, and usually within twenty-four hours after settling down permanently, a short rhizoid (*fig. 3b*) can be seen penetrating the cell. In the meantime the cilium has disappeared, and the oil drop has been growing smaller, being used apparently for the development of the rhizoid. This becomes somewhat club-shaped and soon develops from the swollen tip short branches which eventually grow out into slender branched and somewhat irregular threads (*figs. 16–18*). By means of this rhizoid the young sporangium, as it may now be called, gains nourishment and soon begins to increase in size, so that by the end of the first day after its penetration it may have grown to twice its former diameter. The chlorophyll grains of the host, which normally are distributed rather evenly over the cell wall, are now seen to be congregating in the vicinity of the rhizoid, so that very often all of them are eventually clustered there (*fig. 4*). Sooner or later the young sporangium ceases to swell uniformly and becomes constricted at places, so that it develops a number of folds. These give the elongated forms a somewhat bilateral, and the circular forms more of a radial symmetry. The sporangia keep on enlarging until sometimes they reach over 80 μ in diameter, though often they may increase but little beyond the size of the original zoospores. This variation is determined by condition of leaf, number of competing sporangia, etc. Usually the rhizoid is not extensively developed in the cell, so that after the sporangium begins to grow it is hidden from view.

After the temporary sporangium has attained its full size, its protoplasm becomes faintly divided into areas, about the circumference of which the numerous small oil drops seem to have chiefly congregated (*fig. 6*). In time the small oil drops of each area unite into the large drops of the individual zoospores, and it is by these, rather than by the appearance of visible boundaries, that the zoospores may be distinguished. While the zoospores have been forming, the papilla of dehiscence has been developed at one end or side of the sporangium. There is usually a space here free from zoospores, and the cell wall by

gelatinization forms a distinct hyaline area extending inward in a manner similar to that already described in connection with the germination of the resting sporangia (*fig. 12*). At the time of dehiscence this gelatinized envelope is often protruded at the opening. Into this vesicle the zoospores dart, forming a ball, though it becomes dissolved and the zoospores scattered before all have escaped. The number of the zoospores that is produced depends on the size of the sporangium and varies from three or four up to probably as many hundred. The zoospores are like those formed in the resting sporangia except that they are possibly somewhat smaller. They settle down on the leaf in time, and give rise to secondary temporary sporangia, and even a third generation has been observed on the same leaf. Because of their crowded condition, the failing power of the leaf to furnish nourishment and its diseased condition, these second and third generations, at least in cell cultures, often produced sporangia of smaller size, and their zoospores seemed less active, in extreme cases even failing to move around after being discharged. Sometimes such zoospores had oil drops of a sickly reddish-yellow color. In leaves kept in cultures for some time, occasionally there occurred areas in which the sporangia covered half the surface of the leaf (*fig. 20*).

After a sporangium has discharged its zoospores, if the conditions for growth have been favorable, it is seen that a second sporangium has started within. The rhizoidal apparatus is separated from the sporangium by a septum, which, as soon as the zoospores have escaped, becomes protruded as a papilla, by the further growth of which the second sporangium is formed (*fig. 7*). This process may be repeated until in some few cases as many as five or six sporangia have been developed concentrically. Usually only one or two additional ones are formed, or even only the original one (*fig. 17*). They all dehisce at the same point, though this place of discharge often becomes obscured (*fig. 17*). The successive stages in the development of a temporary sporangium from a given zoospore derived from a resting sporangium are shown in *b, figs. 2–9*. The similar development of

two small sporangia from the zoospores of a temporary sporangium is shown in *figs. 10–15*.

In a few cases, about three weeks after the first infection by the zoospores, there were also found mature resting sporangia similar to those found in the old leaves in the autumn (*fig. 46*). In one case the first sign of these was seen about two weeks after the first infection.

The development of the resting sporangia is quite similar to that described by Büsgen for *Cladochytrium Butomi*. The zoospores penetrate into the leaf much as they do for the formation of temporary sporangia, but in this case all of the contents of the zoospore passes into the enlarged end of the rhizoid-like process. This enlarges into a greatly swollen cell that eventually forms the *Sammelzellen* of authors (*fig. 25*). After this cell has reached its full size, a cell is separated by a partition across the smaller basal end (the end connected with the penetrating zoospore), which is less rich in oil globules than the larger apical or free end. This latter cell may also become divided into two or more, apparently sometimes temporary compartments. From this apical cell or cells are developed one to several very fine simple mycelial threads which connect the *Sammelzellen* to the cell walls of its host (*fig. 29*). On one side of the basal cell near the septum a rhizoid-like process is usually seen. In the same vicinity, evidently connected with this basal cell (though this was not surely made out) and more or less embraced by the rhizoid-like process, there appears a small round cell that rapidly enlarges into the sporangium, while the basal cell becomes empty of its contents (*figs. 27–29*). One or more of the mycelial threads may penetrate into another cell, and there give rise to a similar apparatus (*figs. 28–31*). In this way the fungus spreads from cell to cell. About this time the apical portion of the *Sammelzellen* becomes more or less collapsed (*fig. 29*), but whether this is due to the production of the secondary *Sammelzellen* developed from it, or to a process of fertilization, as claimed by some botanists, was not determined. On the side of the young sporangium there is also often seen a

rhizoid-like process. The exact nature of these processes is not clearly shown, though very often they seem to bind the sporangial cell to the *Sammelzellen.* The sporangium while young contains numerous small oil globules scattered through the protoplasm, but these gradually unite into the one central oil drop. The sporangial walls also gradually thicken, become tinted, and the sporangium is finally matured (*fig. 46*). In the young sporangia there is some indication of a special place for the dehiscence of the cap. Young sporangia that were slightly crushed under a cover glass split off a cap on the side away from the *Sammelzellen.* This is evidently the side that in the mature sporangia is occasionally seen somewhat cupped. Mature sporangia, however, when crushed, do not always split open so regularly.

The infection experiments were all made with the aquatic leaves of seedling plants. It seems very likely that the nature of the leaves determines the character of the sporangia formed, the exposed temporary sporangia being adapted to the peculiar aquatic leaves, and the internal resting sporangia to the aerial leaves. There were some indications that the temporary sporangia did not develop so abundantly on the later leaves, while in none of the aquatic leaves did the mature sporangia develop to such an extent as one might expect if these presented the most favorable conditions for their production. What different conditions determined, as was sometimes the case, the production of both stages on the same leaf was not discovered, but a possible explanation may be that the resting sporangia were developed from zoospores that after settling on the leaf were exposed to the air.

The time relations in the development of the different stages of this fungus are shown approximately by the following observations made in one case:

March 21. Resting sporangia placed in water with young Alisma leaf.

March 23. Sporangia beginning to split off caps.

March 23–24. Active and quiet zoospores present.

March 25. Some zoospores have penetrated leaf to form young temporary sporangia.

March 26. Temporary sporangia of larger size.

March 28. Many temporary sporangia emptied of zoospores.

March 30. Oldest temporary sporangia emptied a second time; second crop of temporary sporangia developing.

April 1. Second crop of sporangia matured; third crop developing; signs of resting sporangia.

April 8. Several mature resting sporangia found.

Despite the luxuriant production of zoospores there are a number of causes that may prevent their forming sporangia. In the first place, they seem to be in their fresh condition a coveted prey for a number of the lower animals. In cell cultures amoebae were seen that had devoured eight or more. Even some of the little heliozoa, scarcely larger than a zoospore, were seen to catch as many as six before they became apparently satisfied. But the most ravenous enemies were occasional rotifers, which did not seem satisfied with a capture of several hundred. In the second place, the zoospores must reach their host and settle down upon it. Very likely many fail to do this. Finally, after reaching the host there are those that never succeed in penetrating into the tissues.

The resemblance of the temporary sporangia to the forms described by Zopf as *Rhizophyton*, on desmids and unicellular algae, suggested the possibility of the temporary sporangia developing on such hosts. In no case, however, where germinating resting sporangia were placed with various species of algae and desmids, were there any indications that the zoospores tried to penetrate them.

The discovery of the temporary sporangia for this Cladochytrium suggests the possibility that other members of the Physoderma section of the genus may also have a similar stage. Through the kindness of Professor Thaxter the writer succeeded in obtaining leaves of *Menyanthes trifoliata* infected with *Cladochytrium Menyanthis*. These leaves had been out doors all winter, and were badly rotted when obtained. The resting sporangia, however, germinated rather readily when placed in water. This Cladochytrium differs from the one on Alisma in the smaller, lighter-colored resting sporangia, which are also

more permanently bound together by the cells of the host. Apparently it has also a very thin outer wall. Its germination differs decidedly in that no cap is split off. Instead, an elongation takes place at one end, as if the inner wall had pushed through the outer wall and the encumbering plant tissue. At the end of this prominent outgrowth is produced the papilla of dehiscence, and the subsequent history is similar to that of the other species (*figs. 21–24*). Attempts to infect young Alisma leaves and various algae with the zoospores from this species were not successful. Unfortunately, seeds or plants of the Menyanthes were not at hand for infection experiments.

Cladochytrium Alismatis was first described in 1833 in Germany by Wallroth (1), who named it *Physoderma maculare*. Its identity has since been fully established, as the original specimens of Wallroth were examined and figured by De Bary (2) in 1864. Fuckel (3) in 1869 transferred the fungus to the genus Protomyces, to which it evidently does not belong. In 1887 Büsgen (5) placed it in the genus Cladochytrium, and also changed the specific name to *Alismatis*. There was no apparent reason for this latter change, unless it was to make a uniform usage in his paper of having all the species named after their hosts. Strict adherence to priority would require the use of Wallroth's rather than of Büsgen's specific name. Schroeter (4, 8) and Berlese and De Toni placed the fungus under Physoderma, Schroeter distinguishing this from Cladochytrium by the absence of temporary sporangia. Fischer (7), on the other hand, does not consider them distinct, and places them with Schroeter's genus Urophlyctis under Cladochytrium.

The fungus has been found only on *Alisma Plantago* L. and its varieties. It is reported in Saccardo's *Sylloge Fungorum* as occurring in Germany, Finland, France, Italy, and Siberia. The following *exsiccati*, which have been examined by the writer, contain specimens: KRIEGER, Fungi saxonici, 681, *Physoderma maculare;* RABENH.-WINT.-PAZ., Fungi europaei, 3977, *Physoderma maculare;* SYDOW, Phycomyceten et Protomyceten, 45, *Cladochytrium Alismatis;* SYDOW, Mycotheca Marchica, 4331,

Cladochytrium Alismatis; SYDOW, Phycomyceten et Protomyceten, 141, *Physoderma maculare.* Numbers 4867 of ROUMEGUÈRE's Fungi selecti exsiccati, 1417 of DE THÜMEN's Mycotheca universalis, and 1 of KARSTEN's Fungi Fenniæ exsiccati, though thus named, are specimens of *Doassansia Alismatis.*

The writer wishes to acknowledge his indebtedness to Professor Thaxter for very helpful assistance in the study of this fungus, and to Professor Farlow for some of the references to the literature and the opportunity to examine herbarium material.

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EXPLANATION OF PLATES II–IV.

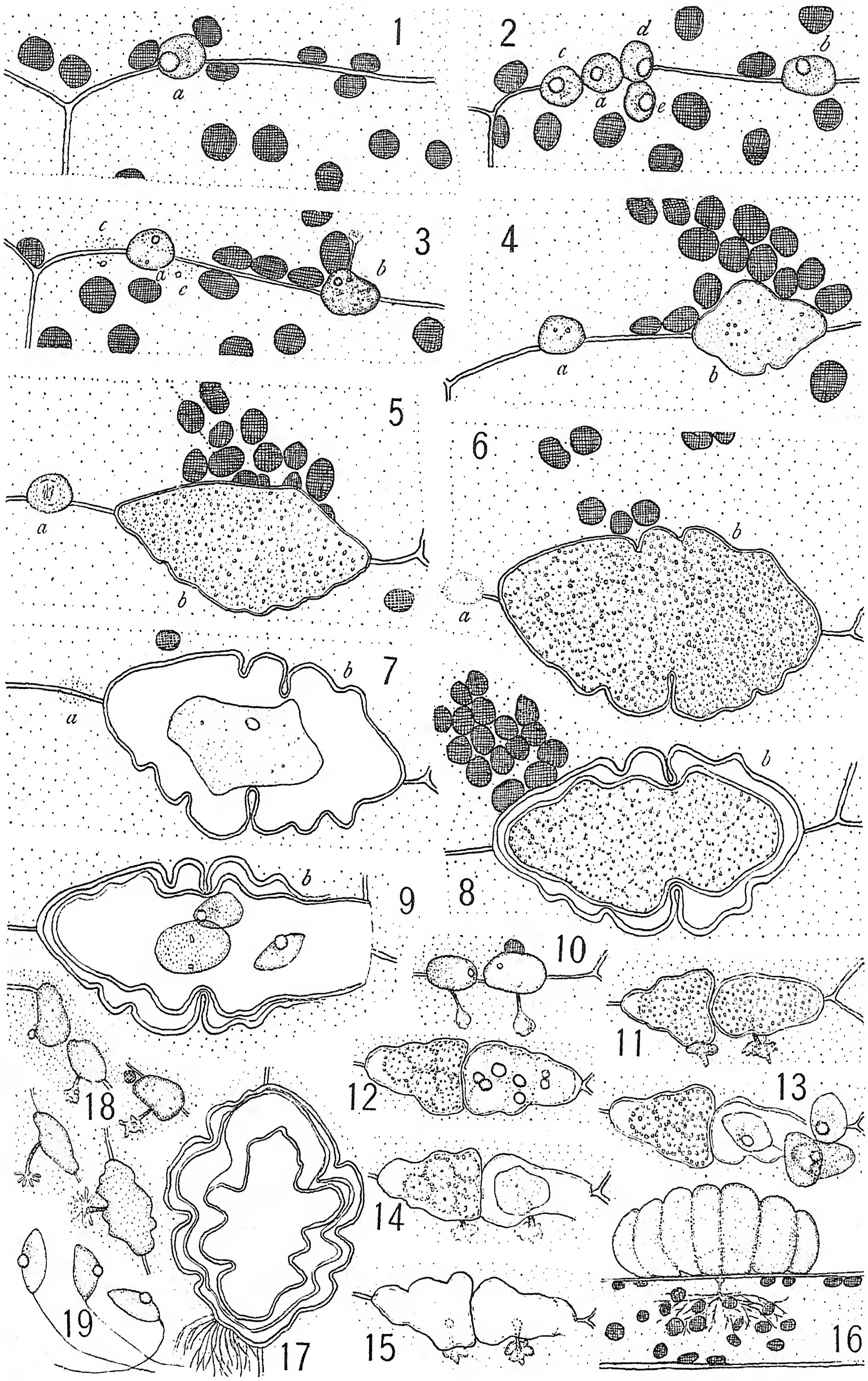
All figures magnified about 850 diameters, excepting *16, 17, 33–39* (about 550 diameters), and *20* (about 300 diameters).

PLATE II.

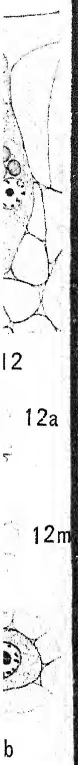
FIGS. 1–20. Temporary sporangia of *Cladochytrium Alismatis.*

FIGS. 1–9. Stages in the development of a temporary sporangium, produced from a zoospore of a resting sporangium, during nine consecutive days.

FIGS. 10–15. Stages in the development of two small temporary sporangia, produced from zoospores of a temporary sporangium, during three successive days.



CLINTON on CLADOCHYTRIUM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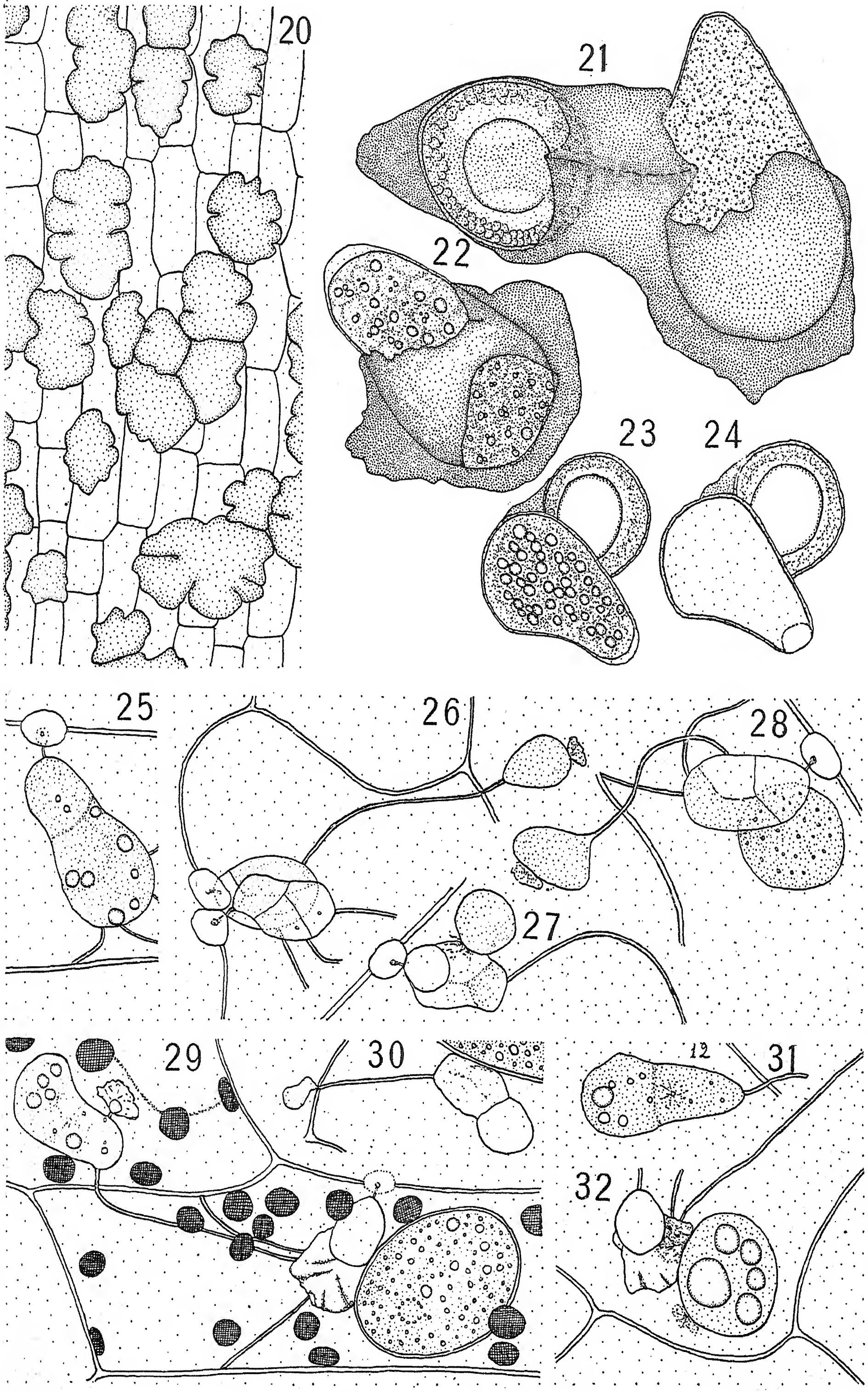

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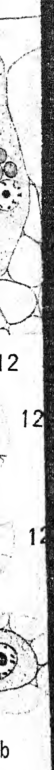
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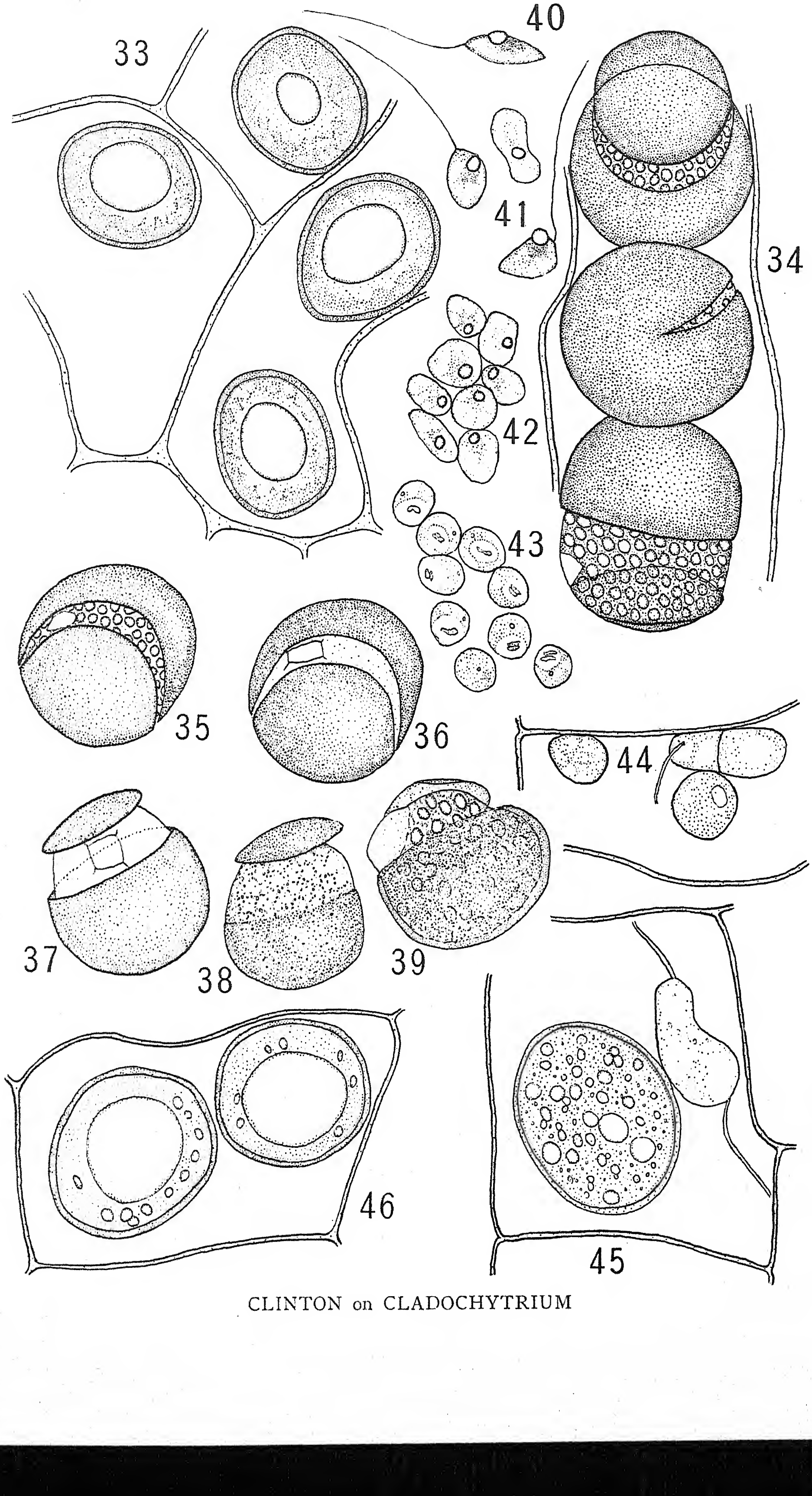

CLINTON on CLADOCHYTRIUM

FIG. 16. Side view of a temporary sporangium showing its rhizoid.

FIG. 17. A temporary sporangium that had emptied three times.

FIG. 18. Several young temporary sporangia, illustrating the early development of the rhizoid.

FIG. 19. Zoospores from temporary sporangium.

PLATE III.

FIG. 20. Epidermal view of portion of Alisma leaf showing numerous immature temporary sporangia.

FIGS. 21–24. Successive stages in the germination of *C. Menyanthis*, the sporangia being bound together by remains of plant cells.

FIGS. 25–32. Stages in the development of the resting sporangia of *C. Alismatis*.

FIG. 25. Penetrating zoospore with *Sammelzellen* and mycelial threads.

FIG. 26. Two penetrating zoospores with *Sammelzellen* and mycelial threads, one of which is forming a young *Sammelzellen* in an adjacent cell.

FIG. 27. *Sammelzellen* with attached young sporangial cell.

FIG. 28. Sporangial cell further advanced.

FIG. 29. *Sammelzellen* collapsing, sporangium about full size, and secondary *Sammelzellen* well advanced.

FIG. 30. The beginning of secondary *Sammelzellen*.

FIG. 31. Secondary *Sammelzellen* dividing into apical and basal cells.

FIG. 32. Secondary *Sammelzellen* collapsing, with attached young sporangium.

PLATE IV.

FIGS. 33–46. Resting sporangia of *C. Alismatis*.

FIG. 33. Section through cells of old leaf of Alisma, showing resting sporangia

FIG. 34. Germinating sporangia still imbedded in woody cell of petiole.

FIGS. 35, 36. The same resting sporangium just before and after emptying its zoospores.

FIG. 37. Side view of an empty resting sporangium.

FIG. 38. Resting sporangium with protoplasmic contents divided into areas, small oil drops, and beginning of papilla of dehiscence.

FIG. 39. Resting sporangium with prominent lateral papilla of dehiscence, about to discharge its zoospores.

FIG. 40. Fresh zoospore from resting sporangium.

FIG. 41. Older and sluggish zoospores.

FIG. 42. Still older zoospores, having lost their cilia.

FIG. 43. Old zoospores going to pieces, showing vacuoles with peculiar vibrating bodies.

FIGS. 44–46. Stages of resting sporangia in cells of young aquatic leaves of Alisma; produced by artificial infection.

BRIEFER ARTICLES.

CLUES TO RELATIONSHIP AMONG HETEROECIOUS PLANT RUSTS.[1]

THE collection and study of Uredineae are beset with a difficulty not found in connection with other classes of plants. A large number of species, principally belonging to the genera Puccinia and Uromyces, inhabit two wholly diverse species of host, and the form of the fungus assumed upon one host gives no clue to the alternate form upon the other kind of host. If teleutospores, for instance, are found upon a grass, there can be nothing detected in the morphology of the rust or of its host, with possible rare exceptions, to indicate whether the corresponding aecidiospores are to be looked for upon a monocot or a dicot, upon a liliaceous, ranunculaceous, or composite plant, or plant of some other family, upon a tree, shrub, or herb; in fact there is no clue whatever. So it comes about that the two halves of heteroecious species are usually gathered separately and listed independently under different genera.

Probably most localities will furnish from a dozen to twenty-five species of aecidia, and *per contra* the same number of unattached teleutosporic forms. Or, to use the prevailing method of expression, there will be so many heteroecious species showing teleutospores, and an equal number of undistributed aecidia. Yet it stands to reason that whether the aecidial or the teleutosporic half be found, still it is but half the species. Contrary to general opinion, there is no definite proof that the one half has any more physiological or taxonomic importance than the other, and the small consideration at present given by collectors and students to the aecidial forms is unfortunate and unwarranted.

For some time I have carried on successful cultures with the heterœcious Uredineae, by which spores of one half of a species were sown, and eventually gave rise to the spores of the other half of the same species. To accomplish this it is necessary to have a pretty clear clue to

[1] Read before the Botanical Socicty of America, Denver meeting, August 1901.

the host on which the second half grows. For instance, if I have teleutospores, found upon a grass in germinating condition, shall I sow them upon a geranium, gooseberry, buckeye, thistle, or some other one of a hundred or more plants known to bear aecidia? I might try each one in succession, and hope eventually to hit upon the right one. But the chances of success by this method are few, in fact, according to my experience, far too few to warrant its use. On the contrary, in order to cherish any reasonable hopes of success it is necessary to possess very definite clues. The method of obtaining these clues I desire especially to call attention to, for it seems to me that observation of this kind will add at times much interest to collecting, and provide valuable data to supplement that usually taken.

To make the problem more concrete, I may state that during the present season I have grown from teleutosporic material the common aecidia on Sambucus, Erigeron, and Aster, and an aecidium on Ribes that appears to be different from the common form. The teleutospores for these four species of rusts came from as many different species of Carex, and have heretofore been erroneously listed as *Puccinia Caricis*. The taxonomic significance of these results will be brought out when the data are ready for publication; it is now only intended to be shown how I came to sow these particular teleutospores upon the right hosts.

In the first place, all observations affording clues (with such exceptions as the similarity in form between uredospores and aecidiospores to be detected only with the microscope, which are so rare as to be negligible) must be made in the field. For the most part they must be made previous to the season when the cultures are undertaken. It is advantageous, indeed, to watch the same rusted plants, or clumps and areas of rusted plants, from season to season. In this way the interest is not so much centered in the specimens carried away, as in the fungus crop that is left behind. When specimens are gathered, they are labeled not only with the usual data, but with sufficiently exact directions so that the spot may be found again. The same host plants are then examined from time to time as the succession of spore-forms appears—spermogonia, aecidia, uredo, amphispores, and teleutospores, all or in part as the case may be. It is like watching for a succession of blooms, and the pleasure of collecting is much enhanced. The whole available territory over which one may ramble or drive now becomes mapped out into specific localities where this, that, or the

other kind of rust grows, and what was mere collecting has resolved itself into an ecological study of absorbing interest.

Only a rich and plentiful occurrence of the rust, whether over wide or restricted areas, is of much value to furnish a clue to relationship. Scattering aecidia or teleutospores generally mean that the source of infection is at a considerable distance, and what is found has come from chance spores blown long distances by the wind. Species vary much as to the distance spores may be carried in condition to start infection, but for our present purpose any distance from a hundred feet to a mile or more is likely to be enough to render our deductions very uncertain.

Probably the easiest and clearest clue is obtained by watching for the first appearance of aecidia. If they can be found thickly covering the leaves of a vigorous plant, especially near the ground, and very few or no aecidia of the same kind upon adjoining plants of the same species, let us search carefully underneath for dead leaves of grass or sedge bearing teleutospores, and for a foot or two around. If these can be found, a little additional search will generally bring to light fragments of last year's inflorescence, by which the specific identity of the teleutosporic host may be determined. The leaves closest to the rusted grass or sedge, which is presumably the source of infection, should bear the thickest sprinkling of aecidial spots. If now a careful search reveals within a radius of ten or twenty feet, only this one grass or sedge bearing teleutospores, we have good reason to assume that the aecidia have arisen from sporidia derived from the recent germination of the teleutospores, and that the two are parts of the same species. By continuing our observations we ought to find after a time, if the weather is propitious, that uredosori are appearing upon the green grass (or sedge) leaves, more abundantly upon those close to the aecidia, and fewer the greater the distance. Only the earliest sori can be of value for our purpose, because uredospores germinate readily, as a rule, and give rise to uredosori that cannot be distinguished from those arising from aecidiospores. If such juxtaposition of the two kinds of spore formation, such coinciding of two centers of infection, be found elsewhere, or for more than one season, especially when other sorts do not occur in a way to cause confusion, we are provided with a strong clue to relationship. Of course, nothing short of cultures will enable one to be perfectly certain. A clue of this sort led to the right sowing for the Aster aecidium mentioned above.

Such good fortune as finding the two halves of a rust so clearly

associated does not occur frequently, although more often than the uninitiated might suppose. A clue of less value may be obtained by finding a limited area monopolized by a single species of grass or sedge, the whole well rusted. We now search for aecidia upon herbs, shrubs, or trees growing within the rusted area, or not to exceed a hundred feet from it. Abundance and nearness, and taking into account all other forms, give us our clue. This was the kind of clue used for the sowing of Sambucus. A Carex of very distinctive habit, species unknown as the plants were sterile, grew in a thick mass, not over ten feet across, that was heavily rusted each season. This spot had been under observation a number of years. No other locality in the immediate region was known for the Carex, and owing to the character of the surrounding ground, it could scarcely find a foothold within a half mile, or possibly much more. No aecidia appeared on any plant growing among the Carex, or within ten feet of it. It was a rich region for plant rusts, and within one hundred feet aecidia were found upon Ranunculus, Oenothera, Impatiens, Eupatorium, Napaea, Sambucus, Ptelea, and Urtica. The aecidia of Ptelea and Urtica were known to belong to other teleutospores; the aecidia on Ranunculus and Oenothera were too abundant and widely diffused through the adjoining region to warrant their being considered. This left four kinds of aecidia sufficiently local to be accepted for trial, and after two season's work it has been positively ascertained that this particular Carex rust must belong to the aecidium on Sambucus.

When a rust occurs very sparingly in a region, but richly developed, or when it is restricted to a rare host, close watch in the immediate vicinity is sometimes rewarded by the discovery of the alternate form. Occasionally this alternate form is so conspicuous that it has been previously collected, but not infrequently it proves to be a sort not before recorded for the district.

The better one becomes acquainted with the rusts of a small region, the more chances there are that his inferences regarding relationship will stand the test of cultures. If he does not make cultures himself, some one may be found who will be willing to undertake the sowings, provided material be furnished. This consists of small living plants of the supposed host of the aecidia, and grass or sedge leaves bearing the rust, the latter gathered during the previous winter and subsequently kept out of doors. Both are readily sent by mail at a trifling cost. Cultures with use of aecidiospores are also important, but less

easily arranged for when they are to be made at a distance from the source of material. Sometimes a single sowing of teleutospores determines the point in question, but for a variety of reasons it usually does not. A common source of difficulty is the failure of the teleutospores to germinate. But these are details pertaining to a separate matter. It will be many years before any large proportion of our numerous heteroecious rusts will be connected with their respective aecidia, and in the meantime all clues to relationship will be much prized by students, and their pursuit will give to the collector an additional source of pleasure.—J. C. Arthur, *Purdue University.*

ROCKY MOUNTAIN PLANT STUDIES. I.

Having spent the past two collecting seasons in the field with Professor Nelson, and having had the opportunity of much observation and some investigation in the herbarium, I have become greatly interested in the varied and beautiful flora of the middle West. No one who comes into close contact with the plants of this region can fail to wish to know more of them. It is my belief that the following plants of this region have so far remained unrecognized. The types are all deposited in the Rocky mountain herbarium of the University of Wyoming.

Marsilia oligospora, n. sp.—Plant $4–7^{cm}$ high: leaflets woolly or becoming glabrous, $6–10^{mm}$ long, $3–7^{mm}$ wide: sporocarp solitary, $4–6^{mm}$ long, $4–5^{mm}$ wide, covered with long straight and appressed (rarely somewhat woolly) pubescence: raphe short: lower tooth short and blunt, upper a mere rounded papilla or wanting: peduncle $5–8^{mm}$ long: sori 5–8 in each valve: megaspores oval to barely oblong, 6–9 in each sorus.

This is a species which has passed for *M. vestita*, but seemingly bears no very close relationship to it. The absence of the sharp upper tooth on the sporocarp, which is so prominent in *M. vestita*, is a mark by which they may readily be distinguished in the field. The number of sori in each valve is less in *M. oligospora* than in *M. vestita*—5 to 8 in former, often 10 or 11 in the latter. The number of megaspores in the two is noticeably different, each sorus in *M. vestita* containing at least 12 and usually 18 to 20. There is also quite a noticeable difference in the shape of the megaspores and in the character of the pubescence of the sporocarp.

The type is number 6560 by *Aven Nelson* and *Elias Nelson*, from Jackson's

hole, Uinta co., Wyoming. It occurred in the bed of a drying-up marshy lake.

Erythronium obtusatum, n. sp.—Bulb rather thick, $3-5^{cm}$ long, deeply imbedded in the soil: leaves oblong-elliptical, $10-20^{cm}$ long, $3-5^{cm}$ wide, obtuse but usually apiculate, never mottled: scape stout, usually 2–3-flowered (1–5): perianth segments pale yellow, drying with a purple tinge (in the field drying white), $2.5-3.5^{cm}$ long, $6-15^{mm}$ wide, usually reflexed: filaments dilated at the base and tapering gradually to a point at the anther; anthers $5-8^{mm}$ long, dark purple: stigma deeply 3-lobed; style very slender, usually equaling or exceeding the stamens.

This species is most closely related to *E. grandiflorum*, from which it differs in its very broad, obtuse leaves, its pale yellow and purple-tinged (at least when dry) flowers, its shorter, dark-purple anthers, and its dilated filaments. It probably has also been referred to *E. Hendersoni*, but this is out of the question since that calls for mottled leaves, purple perianth segments, fleshy subacute auricles at the base of the inner perianth segments, the two scales subglobose-inflated, very slender attenuate filaments, and a shortly 3-lobed stigma (ours deeply 3-lobed), none of which characters *E. obtusatum* possesses. It is barely possible that, in large part, the Erythroniums of Montana, as well as those of northern Wyoming and adjacent Idaho, are to be included in this species.

Two collections of it are at hand: Yellowstone park, Glen creek, 1889, *Aven Nelson* and *Elias Nelson*, no. 5606 (type); Idaho, Continental divide. 1899, same collectors, no. 5480 (co-type).

Erythronium parviflorum (Wats.).—A low plant with opposite leaves: bulb slender, $3-5^{cm}$ long: scape slender, $10-20^{cm}$ long: leaves oblong, tapering gradually to acuteness at both ends, $10-15^{cm}$ long, $3-4^{cm}$ wide: flowers rarely more than one, the peduncles abruptly curved in the form of a shepherd's crook: perianth segments broadly lanceolate-acuminate, $2-3^{cm}$ long, about 1^{cm} wide, bright yellow with a very pale greenish base, strongly reflexed: filaments slender, $1-1.5^{cm}$ long; anthers short, a little lighter than the petals: style clavate: ovary and capsule broadly oblong to even oval, $2-3^{cm}$ long.

This species differs from *E. grandiflorum* principally in being much smaller, in its smaller bright yellow flowers with light colored centers, its abruptly curved peduncles, and its very short anthers. The description of *E. grandiflorum parviflorum* Wats. is very indefinite and incomplete, but undoubtly refers to the above form, which is well worthy of specific rank.

Wyoming, Telephone mines, 1900, Aven Nelson, no. 7833; Colorado, summit of mountains, west of North park, 1899, *G. E. Osterhout.*

Tradescantia Laramiensis, n. sp.—Stems 3–4^{dm} long, branching freely; stems and branches erect, stout, glabrous; the branches arising from the axils of the leaves: persistent radical leaves few, linear, 5–10^{mm} wide; cauline leaves linear, forming a short turgid sheath at the base, a little narrower than the radical leaves; both radical and cauline strongly divaricate (nearly at right angles to the stem); the involucral leaves narrow (2–3^{mm} wide), often equaling the cauline: umbels sessile, terminating stems and branches: flowers very numerous in each umbel (often 50), hanging down in age: pedicels long (2.5–3.5^{cm}): pedicels and sepals remarkably glandular-pubescent: sepals linear-oblong, acute, 10–12^{mm} long: petals dark blue, broad, obtuse, about double the length of the sepals: filament once or twice sharply folded on itself and immersed in the copious wool arising from its lowest segment: ovary ribbed with rows of glandular hairs.

T. Laramiensis is related to *T. scopulorum*, but differs from it in the color of the flowers (*T. Laramiensis* being much darker), in stoutness, in the size and the arrangement of the umbels, in glandulosity of the inflorescence and flower, and in fruit characters. The remarkable pubescence is alone enough to separate *T. Laramiensis* from *T. scopulorum*, but the woolly condition of the filaments and enormous umbels are also decisive characters.

Collected in moist, rocky ground in Halleck cañon, Albany co., Wyoming, by *Aven Nelson*, no. 7455.

Iris pelogonus, n. sp.—Roots thick and fleshy: rootstock stout: stem simple, terete, stout, 2.5–3.5^{cm} long, 1–2-flowered: leaves mostly basal, very dull light green, thick and rigid, half as long to a little longer than the scape, 3–6^{mm} wide: flowers in bud dark blue, fading in age, pediceled; pedicel 1–10^{mm} long: perianth segments prominently nerved, glabrous, not crested, simple, outer ones 4–6^{cm} long, about 2^{cm} wide; the inner a little shorter and about 8^{mm} wide: tube above ovary 8–12^{mm} long: stigmas 12–18^{mm} long, exceeding the filaments by 5 or 6^{mm}: bracts scarious, lanceolate-acuminate, always completely concealing the ovary and usually extending half the length of the perianth segments.

This is a peculiar plant found in the Wasatch Tertiary clays. Its nearest relative is *I. Missouriensis* from which it differs in size, being much smaller, in the marked difference in color, width, and rigidity of the leaves, stoutness of the whole plant, being much stouter in proportion to its size, in the com-

parative length of the bracts with the pedicel, ovary, and flower, and in the relative length of the stigmas and filaments.

Collected at the Bush ranch, Sweetwater co., Wyoming, by *Aven Nelson*, no. 7102.

Alsine validus, n. sp.—Plant glabrous, much branched: stems four-angled, 12–18^{cm} high: leaves lanceolate, broadest at base, 1–3^{cm} long, thick, subcoriaceous, acute, rather rigid, never ciliated at base: bracts very small, 1–3^{mm} long, ovoid or oblong, somewhat acute, scarious: flowers in a usually terminal, many-flowered, compound cyme; pedicels and rays subequal, very variable, 2–5^{cm} long; pedicels straight and rigid, spreading or horizontal: petals deeply two cleft, a little exceeding the sepals: sepals ovoid, with somewhat acute point and scarious margins, 2–3^{mm} long, 1.5–2^{mm} wide: capsule dark brown, shining, nearly twice the length of the sepals, oval, obtuse: styles 3, 3–4^{mm} long, recurved and crested with an abundance of very fine short bristles: seed quite smooth.

The many-flowered compound cyme, stout, thick, wide-spreading pedicels, obtuse capsule, and very small bracts readily separate *A. validus* from *A. longipes*, its nearest relative. The latter has a simple few-flowered cyme, filiform, erect pedicels, more or less acute and more elongated capsule, and also much larger bracts. The character of the inflorescence of *A. validus* is much like that of *A. longifolia*, except that the pedicels are straight and stout instead of filiform and curved.

It was collected in the Centennial valley, Albany co., Wyoming, by *Aven Nelson*, and is the only material of it at hand. The type no. is 7726.—Leslie N. Goodding, *University of Wyoming, Laramie.*

CURRENT LITERATURE.

BOOK REVIEWS.

Plants in their haunts.

ALMOST simultaneously three attractive books have appeared, having for their mission the acquaintance of laymen and amateurs with plants in their natural field relations.[1] *Flowers and ferns in their haunts* is a particularly attractive volume, the full page engravings being unusually clear and true to nature, while at the same time they are artistic gems. The chapters introduce the reader to various topics, from the coming of spring to the aftermath, and many of the topics bring out various ecological features in a purely non-technical manner. Some of the more suggestive chapter headings in this regard are "Along the waterways," "Poisonous plants," "In silent woods," "Flowers of the sun," "Wayfarers."

Our ferns in their haunts, by the well-known student of ferns, Willard N. Clute, aims to present ferns to beginners and fern-lovers in such a way that they will learn to know them easily and yet in a scientific manner. The book is profusely illustrated and contains very much more detailed accounts of both structure and habitat than are to be found in the ordinary manuals. Much in the way of folk lore is added as well. The keys and glossary seem so well gotten together that the identification of ferns must surely be made easier than that of seed plants.

With the wild flowers is a neat little volume that has attained a second edition. It does not stick too closely to scientific facts at all points, as in the cut showing leaf structure. One could wish also that such small and relatively harmless plants as the sun-dew were not included under the blood-curdling title of "ogre-flowers." The impersonation of plants is carried to an extreme and even hurtful degree in this volume.—H. C. COWLES.

[1] WRIGHT, MABEL OSGOOD: Flowers and ferns in their haunts. 8vo. pp. xix + 358, with 57 full page photographs and 118 text illustrations drawn from photographs. New York: The Macmillan Company. 1901.

CLUTE, WILLARD N.: Our ferns in their haunts. 8vo. pp. xii + 332, with 8 colored plates and 185 text cuts and full page plates. New York: Frederick A. Stokes Company. 1901.

GOING, MAUD: With the wild flowers. 16mo. Revised edition. pp. xiv + 271, with 55 text cuts and full page plates. New York: The Baker and Taylor Company, 1901.

MINOR NOTICES.

IN DRYER'S new "Lessons in physical geography"[2] we are pleased to notice a fuller account than is usual in such books under the topic "Plant geography." It is refreshing to see some of the more cogent ecological facts presented in place of the time-worn statements current in the older physical geographies.—H. C. COWLES.

THE FIFTH AND SIXTH parts of Engler's *Pflanzenreich*[3] have appeared, continuing the finely organized and illustrated presentation of the previous parts. Rafflesiaceae (fam. 75) comprise 7 genera and 27 species, and Hydnoraceae (fam. 76) 2 genera and 10 species. Symplocaceae (fam. 242) are represented by the single great genus Symplocos, containing 282 species, 114 of which are described as new.—J. M. C.

THE FIRST FASCICLE of the fifth volume of Thomé's *Flora von Deutschland*,[4] dealing with cryptogams, has appeared, with Dr. Walter Migula as author. The pteridophytes appeared in the first volume, so that the present one begins with the Bryophytes. A general discussion (21 pp.) of the essential features of the group, illustrated by the excellent plates, precedes the systematic presentation. The fascicle includes the Sphagnaceae, comprising 22 species of Sphagnum, and also the beginning of the Andreaeaceae.—J. M. C.

DR. EUG. WARMING[5] has published his sixth contribution dealing with Podostemaceae, presenting the genera Polypleurum, Cladopus, Griffithella, Sphaerothylax, Tristicha, and Marathrum. The very full and illustrated account of the anatomy, morphology, and distribution of these interesting forms follows the method of the preceding papers, which appeared in the same publication in 1881, 1882, 1888, 1891, and 1899. In another contribution the author promises to present a systematic revision of the family, based upon these studies.—J. M. C.

DR. K. GIESENHAGEN[6] has published a very complete monograph of *Niphobolus*, a genus of epiphytic ferns of the oriental tropics and subtropics.

[2] DRYER, CHARLES R.: Lessons in physical geography. 12mo. pp. 430, with 347 figures. New York, Cincinnati, Chicago: American Book Company. 1901.

[3] ENGLER. A.: Das Pflanzenreich. Regni vegetabilis conspectus. Part 5. Rafflesiaceae und Hydnoraceae von H. Graf zu Solms-Laubach. *M* 1.40. Part 6. Symplocaceae von A. Brand. *M* 5. Leipzig: Wilhelm Engelmann. 1901.

[4] Flora von Deutschland. V. Kryptogamen-Flora. Lfg. 1. pp. 1–32, with 7 plates, 5 of them colored. Gera: Friedrich von Zezschwitz. 1901. *M* 1.

[5] Familien Podostemaceae. VI. Memoires de l'Academie royale des Sciences du Danemark. Danske Vidensk. Selsk. Skrift. **11**: 1–67. 1901 (part 1).

[6] Die Farngattung Niphobolus. 8vo. xii+223, with 20 text figures. Jena: Gustav Fischer. 1901. *M* 5.50.

In the first chapter (pp. 1–11) he discusses the general principles of the classification of ferns; in the second (pp. 12–30) a history of the genus is given; and in the third (pp. 21–85) very full details of its morphology are presented, under the headings prothallium, rootstock, root, leaf forms, trichomes, venation, hydathodes, sori, and leaf anatomy. The fourth chapter (pp. 86–223) contains detailed descriptions, both diagnostic and supplementary, of the 49 species, 10 of which are described as new.—J. M. C.

DR. JAKOB HUBER, botanical director of the Museum of Natural History of Para, has issued the first two decades of his *Arboretum Amazonicum*.[7] Each species considered is represented by at least a page of text in Spanish and French in parallel columns, and a plate. The plates are exceptionally fine, being heliotypes from remarkably good photographs. Many of the plants are represented in their natural setting, and the views of tropical plant formations are the finest we have seen. This series of illustrations will be highly prized for its artistic and scientific excellence. In addition to illustrations of prominent genera, several plates represent characteristic plant societies, as a savanna and two illustrations of river bank vegetation. The work will appear in ten parts, at 10 francs a part. The author is to be congratulated upon this valuable contribution to botanical literature.—J. M. C.

ANOTHER FASCICLE of *Plantae Bakerianae*[8] has just appeared. It contains "a somewhat miscellaneous congeries of paragraphs dealing with new or otherwise interesting species" of Mr. Baker's collecting in the Gunnison watershed in the summer of 1901. It is a first installment of volume III of the series, and is published before the completion of volumes I and II. It contains presentations of Ranunculaceae (n. spp. of Cyrtorhynca, Delphinium, and Aconitum), Cruciferae (n. spp. of Draba, Arabis, and Thelypodium), Violaceae (6 n. spp. of Viola), Polygonaceae (n. spp. of Polygonum, Rumex, and Eriogonum), Apocynaceae (2 n. spp. of Apocynum), Asperifoliae (n. spp. of Mertensia and Oreocarya), Labiatae (n. sp. of Monardella), Scrophulariaceae (n. spp. of Castilleia and Pentstemon), Compositae (n. spp. of Senecio, Arnica, Helianthus, Tetraneuris, Psilostrophe, Hymenopappus, Artemisia, and Erigeron), Plantaginaceae (n. sp. of Plantago), Nyctaginaceae (n. spp. of Abronia and Allionia), and Papilionaceae (n. spp. of Thermopsis and Lupinus).—J. M. C.

B. T. P. BARKER[9] has described a conjugating process that precedes spore-formation in an undescribed yeast organism obtained from commercial ginger. He describes the characters obtained from plate-cultures and streak-

[7] Arboretum Amazonicum. Iconographie des plantes spontanées et cultivées les plus importantes de la région Amazonienne. Decades 1 and 2. 4to. Para. 1900.

[8] GREENE, EDWARD L.: Plantae Bakerianae. 3: viii+36. 18 N 1901. [Fasc. I.]

[9] A conjugating "yeast." Phil. Trans. Roy. Soc. B. 194: 467–485. *pl. 46.* 1901.

cultures, but chief interest centers in the spore-formation. Under special nutritive conditions ("starvation") two neighboring cells put out beaks towards one another, which meet and fuse by their tips. The "compound cell" thus formed appears as two ordinary cells attached to one another by an elongated neck. "A few hours after fusion, in each compartment of the compound cell" the spores begin to round off. The author also obtained appearances that he interprets as fusion of the "nuclear apparatus" in the connecting tube. He discusses the various possible interpretations, but concludes that this phenomenon is a sexual process of the simplest kind. He also proposes a new genus to include this form, and suggests the name *Zygosaccharomyces.* What constitutes sexual fusion, as distinct from other fusions, is a question that is becoming increasingly difficult to answer.—J. M. C.

NOTES FOR STUDENTS.

CZAPEK shows[10] that the well known transformation of starch to sugar, which accompanies a lowering of temperature, especially in autumn, can be prevented if the sugar concentration is sufficient. Starch was also formed in guard cells of certain plants immersed in a 10 per cent. cane sugar solution at a temperature of 0°.—H. C. COWLES.

TUCKER and TOLLENS,[11] also Fruhwirth and Zielstorff,[12] have taken up the question of the autumnal migration of carbohydrates, proteids, phosphoric acid, and potash from the dying leaves to the perennial stems of plants. The works of Wehmer and Behrens have given rise to a disbelief in such migrations, Behrens attributing losses of these substances to decomposition and leaching out by rain water. The present authors, however, guarding against such processes, conclude that there are fall migrations of useful substances, though the amount of translocated material is very much less than was once believed.—H. C. COWLES.

D. A. ANDREWS has been investigating karyokinesis in the pollen mother cells of Magnolia and Liriodendron.[13] His conclusions in reference to the first mitosis are that the chromosomes arise from the resting nucleus as irregular masses, without a previous formation of the usual uniform spiral, that the resulting chromosomes are mostly U-shaped, and that they divide longitudinally. The identity of the chromosomes, therefore, is not maintained from the first to the second mitosis, the chromosomes in the latter case arising by the segmentation of an irregular spirem and being at first lumpy bodies that assume the form of a shallow U.—J. M. C.

[10] Ber. d. deutsch. bot. Gesell. **19**: 120–127. 1901.

[11] Jour. für Landw. **48**: 39–64. 1900. [12] Landw. Versuch. Stat. **55**: 9. 1901.

[13] Karyokinesis in Magnolia and Liriodendron, with special reference to the behavior of the chromosomes. Bot. Centralb. Beih. **11**: 134–142. *pl. 1.* 1901.

HATTORI[14] has added another to the numerous contributions on the toxicity of copper. Seedlings of several conifers growing in pots endured much more copper than branches in aqueous solutions. Moist air, by decreasing the transpiration, enabled plants to endure a greater concentration in the water—according to very meager experiments. The copper in water distilled from copper vessels was found sufficient to kill roots. The growth of Aspergillus and Penicillium was stimulated by dilute copper; in the case of Aspergillus this did not interfere with the formation of conidia. In all cases the concentration of copper is given in the extremely inconvenient form of a per cent. of $CuSO_4+5H_2O$.—E. B. COPELAND.

BENECKE[15] has reinvestigated Cakile and Salicornia in order to test the recently expressed view of Diels that these plants decompose considerable quantities of NaCl in their metabolic activities. Diels observed gradual decrements of salt in distilled water cultures, especially in Cakile, and he supposed that sodium malate, or some such substance, was formed, setting free the chlorine. Benecke thinks that Diels failed to account for the increase of other substances, especially water, in his plants, and that consequently his percentage comparisons were wrong. The present author uses similar methods, and concludes that the chlorine content suffers no decrease in distilled water cultures. Apparent decrease may be due to increase of water, as noted above, and also to variations in chlorine content in leaves of different ages, the old leaves being relatively poor in NaCl.—H. C. COWLES.

IN A RECENT PAPER, Professor Guignard[16] has described the details of of double fertilization in *Naias major*, which do not differ essentially from those in other forms recently described. The male nuclei are elongated, but do not take on the vermiform appearance so conspicuous in the Compositae. One synergid disintegrates soon after the entrance of the pollen tube, and the other remains intact for some time after the fertilization of the egg, and may itself be fertilized instead of the endosperm nucleus. In the latter case the endosperm does not develop. The fertilized egg immediately divides, one figure showing the fertilized endosperm nucleus in the spirem stage, while the embryo is two-celled. In all previously described cases of double fertilization the endosperm nucleus invariably divides before the fertilized egg shows any signs of division. In many instances two embryos were observed side by side, with the unfertilized endosperm nucleus lying between them. Two of the antipodals soon show signs of breaking down, but the upper one

[14] Studien über die Einwirkung des Kupfersulfats auf einige Pflanzen. Jour. Coll. Sc. Imp. Univ. Tokyo **15**:371–394. 1901.

[15] Jahrb. für wiss. Bot. **36**: 179–196. 1901.

[16] La double fécondation dans le *Naias major*. Jour. de Bot. **15**: 1–9. *figs. 1–14*. 1901.

continues to enlarge for a long time after fertilization. The chromosomes are very long, the gametophyte number being six, the smallest number yet reported in seed-plants.—W. J. G. LAND.

INVESTIGATIONS dealing with the influence of the medium on plant development continue to multiply. Pethybridge[17] has experimented with various salt solutions on the development of wheat, finding that the dilution of nutrient solutions or the addition to them of NaCl causes root elongation, decrease in leaves, shoots, and root diameter, and increase in the thickness of endodermis walls; the stomata on the under leaf surface almost wholly disappear. Root hair formation is repressed in NaCl solutions and in increased light. Arker[18] finds that the rapidity of growth of the roots of *Lupinus albus* is facilitated by introducing air currents, especially if somewhat rarefied, into the medium. Beauverie[19] found that an increase of osmotic pressure caused a reduction in the aerial portions of fungi, together with a lateral dilatation of the cells; in very strong solutions the entire plant often became submerged. A more recent study of various seed plants has yielded similar results. Beauverie refers the well known root curvature in water to differences in osmotic pressure rather than to aerotropism, finding that the roots grow straight down in concentrated solutions. The aerial axis becomes reduced in height and broadened laterally as in fungi. The anatomical structure is affected also; a thick cork layer is developed very early in strong solutions; but this is not the case where the pressure is weak.— H. C. COWLES.

BERNARD[20] has presented to the Paris Academy of Sciences two papers which will be certain to incite interest and further investigation. In the first paper, entitled precocious tuberculization in plants, he recalls the production of tubercles on legume roots and coralloid processes on various tree roots through stimulation by bacteria and fungi. Bernard shows the remarkable resemblance between the tuberculous organs of lycopods and orchids, two widely separated families. The gametophyte and sporophyte of Lycopodium and the sporophyte of several orchids show essentially similar organs, and are infested by similar fungi, and in all cases the fungus is Fusarium or a related form. Of a large number of tuberous plants investigated by Stahl in his recent mycorhiza studies, Corydalis alone is found to be without fungi. In his second paper Bernard makes the surprising statement that it is his belief that the tubers of the potato are essentially galls and due to fungus infection. He shows that *Fusarium Solani* is always present in the tubers, and it seems likely that this fungus causes the arrest of the terminal bud and

[17] Inaugural dissertation. Göttingen. 1899. (See Bot. Centralb. **87**: 235. 1901.)

[18] Inaugural dissertation. Erlangen. 1900. (See Bot. Centralb. **87**: 235. 1901.)

[19] Compt. Rend. **132**: 226–9. 1901.

[20] Compt. Rend. **131**: 626–629. 1900; **132**: 355–357. 1901.

the development of hypertrophied tissues, which become filled with starch. The author's experiments, while not yet conclusive, strongly support his theoretical conclusions, since a decided parallelism is seen to exist between the amount of tuber formation and the development of the fungus. However, no cultures entirely free from fungus have yet been made. Bernard notes than when the potato was introduced into France, tubers could not be produced from seed cultures, presumably because *Fusarium Solani* did not then infest the soil.—H. C. COWLES.

TANSLEY and CHICK[21] have made some interesting anatomical studies on the conducting tissue system of bryophytes. The main purpose of the investigation was to shed light on the probable origin of conducting tissues in plants. In general the authors confirm the work of Haberlandt, who showed that the Polytrichaceae have a more complex conductive system than some so-called vascular plants. The tracheids of the liverwort Pallavicinia were studied and were shown to conduct eosin solutions more rapidly than neighboring tissues, though much more slowly than Haberlandt found to be true in moss bundles. The rhizome of Polytrichum was found to have structures resembling the roots of seed plants, viz., a typical endodermis with suberized walls, a pericycle, and a central cylinder with a triarch arrangement of the hydroids and leptoids. It would seem from this that the rhizome of Polytrichum may well be called a root. The aerial stems were found to agree with Haberlandt's description. The authors think from the liverwort evidence that demands for more efficient conduction were first met by cell elongation and lignification of the walls. This idea is favored also by experimental evidence, as has been often shown. In most mosses the leaf and stem bundles are not connected, indicating a possible double origin of conducting bundles. Mnium and Bryum show incomplete connections, while Polytrichum and its allies show bundles of hydroids and leptoids permeating the entire plant, as in ferns and seed plants. In Polytrichum there is a hydrome mantle outside the central cylinder of leptome and hydrome, in this respect resembling ferns. The authors think that this outer mantle may be the downward projection of the leaf bundle, the original stem bundle being at the center.—H. C. COWLES.

THE STRUCTURAL DIFFERENCES between the white and green parts of variegated leaves has been recently noted.[22] The general subject of the "panachirung" (perhaps this term may be rendered into English as "albescence") of leaves has had considerable investigation of late. Timpe[23] finds that the anatomical features are much as noted in the review of Rodrigue's paper; in some cases (as Abutilon) the albescent portions are thicker than the

[21] Annals of Botany 15: 1–38. 1901. [22] BOT. GAZ. 31: 209. 1901.

[23] Inaugural dissertation. Göttingen. 1900. See Bot. Centralb. 85: 75. 1901.

green portions of the leaf. Thin albescent parts are due to a reduction in palisades and intercellular spaces. The author finds a close relation to exist between chlorophyll development and leaf thickness, including the development of palisade cells; if chlorophyll stops abruptly in a variegated leaf, the thin part begins abruptly and palisades cease at once; if the chlorophyll fades out gradually, the leaf gradually becomes thinner and palisades gradually cease. These results and those of Rodrigue seem to throw doubt on Stahl's theory that palisades are due to the direct influence of light, and relate them rather to the presence of active synthesis; the reviewer, however, has observed palisade cells in the albescent parts of many leaves. Timpe finds that albescent portions of leaves redden more than the green portions; this harmonizes well with Overton's conclusions,[24] since the white leaf parts are found to be rich in tannins and sugars, though poor in starch.

Laurent,[25] discusses the origin of albescence in plants. There are two types, those coming from spores, and those that reproduce by seed. The latter type is ordinarily thought to be not responsive to external factors. In some situations plants which are commonly albescent have green leaves, and in other situations the reverse is the case. Laurent thinks that some enzyme intervenes to cause a modification in the distribution of the chlorophyll.

Molisch[26] observed that *Brassica oleracea acephala* becomes albescent in cold greenhouses in winter, and becomes green again in summer, the whitening beginning in October and reaching its maximum in February. The author thus holds with Laurent that albescence may be affected by external factors. In the case of Brassica the author thinks that temperature is the factor involved, since warm greenhouse cultures do not show the phenomenon.—H. C. COWLES.

ITEMS OF TAXONOMIC INTEREST are as follows: F. STEPHANI (Bull. Herb. Boiss. II. 1:1141. 1901) has segregated a new genus (*Cuspidatula*) of liverworts from Anastrophyllum, the 4 species included belonging to the East Indian and Australian region.—B. L. ROBINSON (Rhodora 3:270–276. 1901) has published a synopsis of the North American species of *Euphrasia*, recognizing 7 species, 2 of which are new (*E. Williamsii* from Mt. Washington and *E. Randii* from Mt. Desert.)—THEO. HOLM (Ottawa Nat. 15:175–183. *pls. 11–14.* 1901) has described 3 new Canadian species of *Gentiana* belonging to § Crossopetalae.—S. B. PARISH (Proc. Calif. Acad. Sci. III. Bot. 2:159–172. 1901) has revised certain troublesome species of *Solanum* of the *S. Xanti* and *S. umbelliferum* group, describing 3 new species and 4 new varieties, and giving detailed lists of collections.—HELGI JÓNSSON (Botanisk Tidsskrift 24:127–155. 1901) has published an account of the Rhodophyceae as the first of a series of papers on the marine algae of Iceland, 2 new species

[24] BOT. GAZ. 27:491. 1899. [25] Bull. Soc. Roy. Bot. Belg. 39:6–9. 1900.

[26] Ber. deutsch. bot. Gesell. 19:32–34. 1901.

being described.—JOHS. SCHMIDT (*idem* 157–221. *pls. 2–4*) has published Part IV of his *Flora of Koh Chang* (Gulf of Siam), W. and G. S. WEST contributing the fresh water Chlorophyceae (121 spp., 9 new), TH. REINBOLD the marine algae (62 spp., 2 new), M. GOMONT the Myxophyceae hormogoneae (27 spp., 2 new), and JOHS. SCHMIDT the Peridiniales (44 spp.), *Ostreopsis* being a new genus.—F. V. COVILLE (Proc. Wash. Acad. Sci. **3**: 569–576. 1901) has segregated two new genera from Cassiope, *Harrimanella*, containing *C. stelleriana* DC. and *C. hypnoides* D. Don, and *Arcterica*, containing *C. oxycoccoides* Gray.—P. A. RYDBERG (Bull. Torr. Bot. Club **28**: 605–643. 1901) has published a monograph of the American species of *Limnorchis* and *Piperia*, both genera having been separated by him from Habenaria, in the former genus 24 species being recognized (5 new), and in the latter 9 (3 new).—G. E. OSTERHOUT (*idem* 644–645) has published new species of Linum, Mentzelia, Artemisia, and Agoseris from Colorado.—A. ENGLER (Bot. Jahrb. **30**: 289–445. *pls 9–22.* 1901), in continuing his studies of the African collection of W. Goetze, has published, in addition to numerous new species, a new genus (*Stenadenium* Pax) of Euphorbiaceae.—RUDOLF WAGNER (Œsterr. Bot. Zeitsch **51**: 465. 1901) has described a new genus (*Cyphochlaena*) of grasses from Madagascar, of the tribe Arundinelleae.—J. M. C.

THOMAS[27] has made a comparative and experimental study of subterranean leaves or scales. They correspond morphologically to sheaths, petioles, or leaf blades, and in all cases differ widely from their morphological homologues. This divergence is particularly great where scales correspond to leaf blades, the palisades, lacunae, bundles, mechanical cells, and epidermal cuticle being much reduced or absent. When aerial branches are made to grow in the soil, leaf primordia develop into structures whose anatomy is like that of scales; leaf blades are reduced, petioles are less reduced, or sometimes even greatly enlarged as in Trifolium, channeled petioles change to flat organs, collenchyma and bundles are reduced, the parenchyma is more compact and with polygonal, instead of rounded cells. The upper epidermal walls are less cutinized, and the lower walls more cutinized, than in normal leaves, stomata are entirely lost, palisades and air spaces are reduced, and reserve foods are stored in abundance. When subterranean branches are made to grow in the air, scale primordia develop into leaves, stomata appear, palisades, vascular tissues, and air spaces are more fully developed.

Some very interesting conclusions are drawn by the author. The scale is found to be the morphological equivalent of the leaf part nearest the base, *i. e.*, the blade in a sessile leaf, the petiole or sheath in a petioled leaf. The changes observed are quite different from the effects of mere darkness, nor are they to be attributed to arrested development, since they differ widely

[27] Rev. Gen. Bot. **12**: 394–404, 417–433. 1900.

from early leaf conditions. The reductions in palisades, air spaces, bundles, and collenchyma are analogous to conditions in young leaves, or to leaves grown in the dark (though the reduction is more complete in the soil); but the entire loss of stomata, the great development of reserve foods, and the strong cutinization of the lower epidermis are without a parallel in other conditions than those furnished by a sojourn in the soil. In some cases, notoriously in *Lysimachia vulgaris*, palisades appear in all conditions, even in leaf primordia while still in the bud and four or five centimeters below ground. The author consequently inclines to agree with Pick that palisades are due to hereditary influences, and that their direction only is determined by light. Thomas also thinks that the changes produced in soil conditions are in direct response to the new needs which arise there.—H. C. COWLES.

STRASBURGER,[28] in a very comprehensive paper, has taken up the whole subject of protoplasmic continuity in plant cells. He proposes the term *Plasmodesmen* for the connecting fibers. Among others, new observations are figured and described for Viscum, Pinus, Phytelephas, Nerium, the sieve tubes of Wistaria and Vitis, leaf cells of mosses, and the cells of grafts of Abies and Picea. But the paper is devoted fully as much to a critical résumé of the literature as to the recording of new observations. To recapitulate all the points made is plainly impossible in a brief review, and only a few of the most important will be mentioned. Kienitz Gerloff's view that the *Plasmodesmen* do not originate in the fibers of the central spindle is confirmed, and they must hence arise secondarily after cell division, but the question as to just how and when they are formed is left unsettled. Figures are given from Pinus and Wistaria confirming the prevalent belief that the thicker connecting strands of the sieve tubes originate as *Plasmodesmen*. As to the functions of *Plasmodesmen*, Strasburger confirms Gardiner's view, that in the endosperm of Tamus they serve to transport enzymes. In the medullary rays of Abies they may serve to transport proteids. That protoplasmic streams in general, however, pass through the fibers, or that they serve, for example, for the withdrawal of protoplasm from the leaves in the fall, is shown to be entirely unproved. The importance of the *Plasmodesmen* for transmitting stimuli and for the normal development of organs is shown by a number of very interesting observations and experiments. Complete plasmolysis results in the withdrawal of the *Plasmodesmen* from their pores in Mnium. Though when washed out the plasmolyzed cells again press upon the cell walls, the *Plasmodesmen* are not reestablished, and the tissue, although it may live several weeks, develops no further and ultimately dies. Plasmolyzed root tips of *Vicia Faba* cannot afterward react geotropically. This may be due to the loss of the *Plasmodesmen*, or to injury of the

[28] Ueber Plasmaverbindungen pflanzlicher Zellen. Jahrb. wiss. Bot. **36**: 493–610. *pls. 14–15*. 1901.

young cell walls. The existence of *Plasmodesmen* between the symbiont cells in grafts of Abies and Picea is shown conclusively. Such facts as that a grafted shoot does not produce roots at its base, and that a grafted lateral twig may bend up and replace a lost central shoot, are doubtless due to morphaesthesia, the stimuli being transmitted through the *Plasmodesmen* of the graft. The question as to whether the *Plasmodesmen* involve continuity or only contact of fibers sent out from adjacent cells is fully discussed, but owing to technical difficulties the facts in the case remain undiscovered.— * * *.

HUGO MIEHE[29] has recently investigated certain cases of nuclear migration in the epidermal cells of some monocotyledons. The fact of the polarity of the epidermal cells that form stoma mother cells had been established by the researches of Strasburger,[30] and more recently by those of Miehe[31] himself. Miehe now finds that by subjecting leaves of *Allium Cepa* or *Hyacinthus orientalis* to a great centrifugal force (2500 × gravity), with the basal ends of the leaves directed outward on the centrifugal machine, the polarity of the cells is exactly reversed, *i. e.*, the stoma mother cells are formed in the basal rather than in the distal part of the epidermal cells. By making stationary the tips of some leaves, to the bases of which small parts of the bulbs were left adhering, and allowing them to grow for some time under favorable conditions, the consequent change in the direction of cell growth produces a corresponding change in their polarity. Miehe thinks that the direction of cell growth is the important factor in determining the position of the stoma cell under ordinary conditions.

Perhaps the most interesting part of the paper, however, is the account of the migration of the nuclei from cell to cell, a process that Miehe found to occur as a response to the stimulus produced by wounds. In such cases the nuclei migrate toward the wounded cells, and when they come near the cell walls put out fine processes that protrude through minute pores in the wall. The whole nucleus passes through such a pore and forms a dense mass on the opposite side of the wall. From the fact that in material killed in Flemming's fluid and stained with the triple stain the denser part of the nucleus (including the pointed processes and the part that has already passed through the wall) stains red, while the less dense part stains blue, Miehe supports Fischer's contention that differentiation in staining is due largely to differences in physical rather than chemical structure of the various

[29] Ueber Wanderungen des pflanzlichen Zellkernes. Flora **88**: 105–142. *pl. 11.* 1901.

[30] Ein Beitrag zur Entwickelungsgeschichte der Spaltöffnungen. Jahrb. wiss. Bot. **6**: 301. 1866.

[31] Histologische u. experimentelle Untersuchungen über die Anlage der Spaltöffnungen einige Monokotylen. Bot. Centralb. **78**: 321, 353, 385. 1899.

bodies. Both the enucleated and multinucleated cells formed by the migration of the nuclei generally die. The neighboring cells then grow into the region thus left vacant. The nuclei generally wander to that part of the cell wall where it is growing most rapidly.

The paper constitutes a very suggestive contribution to a comparatively new field in physiological research. All the material experimented upon was afterwards killed in Flemming's or Carnoy's killing fluid and stained with the triple stain. Such a combination of experimental and histological technique is to be commended as a method by which in many cases more accurate results in the study of the physiology of the cell may be acquired than by the use of either method alone.—H. G. TIMBERLAKE.

TEODORESCO[32] has published some valuable organographic results that should have been noted sooner. The topic of the first paper is the influence of different luminous radiations on form and structure, and the author makes general conclusions of a very satisfactory nature. He finds that in all cases blue light acts most like white light, and green most like the dark, while red light is intermediate. For example, leaves show a maximum of surface in blue light, and a minimum in green, while stems elongate most in green light and least in blue. Some leaves (as in the Crassulaceae) and most petioles agree with stems. Petioles that elongate most in blue light elongate more in white light than in the dark. Palisade cells, chloroplasts, conductive cells, and bark develop best in blue light, least in green. Some roots elongate more in white light than in the dark, of others the reverse is true, while still others are neutral. Blue light, as compared with green light also shows roots to be of three classes. The author holds that blue light increases synthetic energy as compared with red or green light.

The second paper[33] treats of the indirect action of light on stem and leaf. The author grew plants wholly in the light, wholly in the dark, and partly in the dark, hoping to settle as between the view of Sachs that leaves can develop fully in the dark if well nourished by means of other leaves in the light, and the view of Frank and others that light has no such indirect influence. Most experiments confirmed Sach's well-known investigations, leaves growing to a greater size in the dark if other leaves on the same plant were in the light; the leaves were also thicker, and the bundles, mechanical tissues, palisades, and epidermis more developed than on plants wholly in the dark. The stems were longer in partly lighted plants than in either of the other cases, thus agreeing with Sachs. In several lianas, however, Teodoresco finds with Frank that indirect light differs in no respect from total darkness.

In a third paper[34] Teodoresco gives the results of his studies on the

[32] Ann. Sci. Nat. Bot. VIII. **10**: 141–263. 1899.

[33] Rev. Gén. Bot. **11**: 369–397, 430–435. 1899.

[34] Rev. Gén. Bot. **11**: 445–470. 1899.

influence of carbon dioxid on form and structure. Plants were grown in atmospheres almost without carbon dioxid, also in atmospheres containing about 2 per cent. of this gas. Marchantia cultures with but little carbon dioxid showed great reduction in the width and length of thallus, as compared with normal plants; no gemmae were formed, neither the characteristic algoid chlorophyll tissue. Air spaces and chloroplasts were much less abundant, but the colorless parenchyma developed normally. The results are almost exactly those of weakened light. In seed plants Teodoresco finds that so long as seedlings are using reserve foods carbon dioxid retards stem elongation. In older plants carbon dioxid favors the elongation of stems, the enlargement of leaf surfaces, and the rich development of bast, wood, palisades, and air spaces.— H. C. COWLES.

SEVERAL PAPERS have appeared which add considerably to our knowledge of the physiological ecology of chlorophyll and carbohydrate synthesis. Among these the most important are by Griffon. The first paper[35] deals chiefly with the relations between color and the synthesis of carbohydrates. Griffon shows that, although a general ratio exists between the amount and color of the chlorophyll and the amount of CO_2 which is broken up, in many cases the chlorophyll present is no measure of the chlorophyll function; for example, in alpine plants the synthesis is greater and in halophytes it is less than the amount of chorophyll would lead one to expect. This result confirms the previous work of Bonnier, and is contrary to the view of Pfeffer. In some green half-parasites and symbiotic saprophytes the gas exchanges associated with respiration are actually greater than those associated with carbohydrate synthesis. The significance of these results is not clear, but the author holds that differences in the cell structure of the chlorenchyma explain some cases. Perhaps the most rational theory, however, is that there are several varieties of chlorophyll, some possessing active synthetic powers and others not; this view agrees with recent spectroscopic studies by Etard, who claims to have found a large number of varieties of chlorophyll, and sometimes two or three in one plant species.

Another interesting set of results has to do with the influence of colors other than green on the synthetic processes. Stahl, Pick, and others have held that the red anthocyan colors favor synthesis, whereas Jumelle and Jönsson have held that they retard it. Griffon thinks that they have no influence whatever. Although red leaves commonly do less chlorophyll work than green leaves in related species, this is due to the generally smaller amounts of chlorophyll in red leaves. Red leaves rich in chlorophyll are as active as green leaves of the same or similar species. Nor does the author regard anthocyan as prejudicial in chlorophyll formation, even though red leaves are so

[35] Ann. Sci. Nat. Bot. VIII. 10:1–123. 1899.

frequently poor in chlorophyll. Griffon agrees with Overton[36] that the autumnal colors are due to excessive carbohydrate concentration in the chlorenchyma. He also holds with Bonnier that the synthetic power of xanthophyll is relatively inconsequential. The influence of various external factors on carbohydrate synthesis is well presented but must be omitted here, except to state that Griffon finds that chlorophyll formed in the dark (as in conifer seedlings) acts normally. In this connection it may be noted that Bouilhac[37] has found chlorophyll in Nostoc by spectroscopic tests and has succeeded in observing the formation of chlorophyll in this form in the dark, when it is fed with carbohydrates, such as glucose. Griffon thinks that the development of chlorophyll in the dark is in all cases associated with a supply of reserve foods.

In his second paper[38] Griffon measured the amount of carbohydrate synthesis in solar light which has traversed one or more leaves. That certain light rays are cut off in traversing leaves is well known, but few previous attempts have been made to measure synthesis. Nagamatz used the starch method, which is now known not to be accurate. Griffon uses the gas method, and finds that active synthesis takes place in the second leaf even where light has traversed a thick and densely green leaf like Hedera or Laurus; in the case of such plants, where a leaf is shaded by two leaves, respiration commonly exceeds synthesis. The synthethic energy of the second leaf varies, according to differences in amount of chlorophyll and chlorenchyma, and to undetermined factors (probably specific chlorophyll differences), between one-half and one-forty-eighth of that in the leaf which receives unmodified solar rays. In diffuse light the synthethic energy of the second leaf is of course still less. To summarize, respiration generally exceeds synthesis where light has traversed two leaves in the sunlight or one leaf in the shade.

Linsbauer[39] has investigated the transparency of a number of leaves with the use of Wiesner's photometric methods. Only the more refrangible rays were studied. Leaves vary widely in the amount of light that they transmit, sun leaves of Cytisus and Cornus transmitting only 0.0003 of the light offered them, while shade leaves of Fagus transmit 0.02. In general, shade leaves transmit much more light than do sun leaves. The same species and even the same leaf (as N. J. C. Müller showed) shows wide variations, the shade leaf of Cornus transmitting seven times as much light as the sun leaf; perhaps these differences are due in part to variations in the amount of the

[36] Rev. Gen. Bot. **12**: 209–223, 272–288. 1900.

[37] Bot. Gaz. **27**: 491. 1899.

[38] Comp. Rend. **126**: 1583–1586. 1898.

[39] Bot. Centralb. Beihefte **10**: 53–89. 1901.

products of synthesis which are present. The white portions of variegated leaves absorb much more light than does the chlorophyll alone.

Reference has been made previously[40] to the work of Goldflus who found an amount of synthethic energy in the chlorophyll layer underneath the cork of trees that is surprising in the light of the experiments of Griffon and Linsbauer, as noted above.— H. C. COWLES.

ONION smut[41] and grape rots[42] are the subjects of two bulletins from the Ohio Experiment Station. The smut of the onion is able to penetrate the young plant only while leaving the seed or very soon thereafter. As it has no effect upon the sets, it is perfectly safe to put the latter into an infected field, if they have been grown in a seed bed free from smut spores. In certain parts of Ohio where growing sets from seeds is practiced, the loss from smut has amounted to 25 to 40 per cent., and even more, *i. e.*, to 100 to 200 or more bushels of sets per acre. Preliminary experiments go to show that by sprinkling the seeds, after they are scattered in the rows, with a solution of 1 oz. of 40 per cent. formalin in 2 to 3 gallons of water, until well moistened, and then covering with earth, the loss from smut is very greatly diminished. Ground burnt lime applied in the usual manner at a rate of 150 bushels per acre is also recommended as worthy of trial. Further experiments are to be undertaken to determine the commercial value of these treatments.

The grape rots causing the most damage in Ohio are white rot (*Coniothyrium diplodiella*) and black rot (*Laestedia bidwellii*). The former seems not to have been well distinguished from the latter, which may account for the paucity of the literature on the subject. It is less amenable to treatment, possibly from the fact that it is at its maximum almost immediately preceding ripening of the grapes, at a time when Bordeaux mixture and the more permanent fungicides cannot be used for fear of decreasing the market value of the fruit. It is only by constant spraying, beginning before the flower buds open, and continuing as close to the maturity of the grapes as possible, at least eight or nine sprayings a season, that the best results can be obtained in the grape regions of Ohio.— ERNST A. BESSEY.

[40] BOT. GAZ. 31: 440. 1901.

[41] SELBY, A. D.: Onion smut. Preliminary experiments. Bull. Ohio Agr. Expt. Sta. 122: 71–84. *figs. 1–4.* December 1900. Wooster.

[42] ——— and HICKS, J. F.: Grape rots in Ohio, Experiments in the prevention of grape rot. *ibid.* 123: pp. 85–102. *figs. 1–3.* January 1901.

NEWS.

Dr. Eugen Warming has been appointed director of the Geological Survey of Denmark.

Dr. Bradley M. Davis, of the University of Chicago, has returned to his work from a stay in Paris.

An excellent portrait of the late Thomas Meehan was published in *Meehan's Monthly* for December last.

Dr. E. B. Copeland, formerly of the University of West Virginia, is engaged in research work at the University of Chicago.

The distinguished mycologist, Professor Robert Hartig, director of the Botanical Institute of Munich, died October 9, 1901.

We learn through *Science* of the recent death of Professor Miguel Colmeiro, director of the Botanical Garden at Madrid, aged 86.

Miss Josephine E. Tilden, of the University of Minnesota, has just returned from a brief winter exploring trip on the Vancouver coast.

M. Durand has been appointed director of the Botanical Garden in Brussels, in place of M. Crépin, who has resigned because of ill health.

Dr. Charles J. Chamberlain, of the University of Chicago, is spending the current academic year in Europe, chiefly at the University of Bonn.

Professor Wettstein of Vienna has returned from his Brazilian trip and reports that he has secured valuable collections from hitherto unexplored regions.

Dr. John G. Coulter, formerly of Syracuse University, has been appointed professor of botany in the Manila Normal School, Philippine islands.

Dr. Richard Sadebeck, professor of botany, and director of the botanical museum and laboratory connected with the Colonial Institute at Hamburg, has recently retired.

The director of the Botanical Survey of India has projected a series of regional floras; the first of these, dealing with the Bombay presidency, has just been issued.—*Nature.*

The Society for Plant Morphology and Physiology held its fifth annual meeting at Columbia University, December 31 and January 1, under the presidency of Dr. Erwin F. Smith.

BENJAMIN H. SMITH has been elected director, John W. Harshberger recorder, and Stewardson Brown curator of the botanical section of the Academy of Natural Sciences of Philadelphia for the ensuing year.

PROFESSOR F. LAMSON-SCRIBNER, chief of the Division of Agrostology of the Department of Agriculture, has been given charge of the Bureau of Agriculture to be organized in the Philippines. He will sail with his family February 1.—*Science*.

MR. K. FUJII, assistant in botany in the Imperial University of Tōkyō, has been sent by his government to Germany for three years' study in morphology and cytology. After stopping for a brief visit to the botanical laboratories of the University of Chicago, he left directly for New York and sailed for Germany.

MR. D. G. FAIRCHILD, who is government expert in plant introduction, is on his way to Ceylon and southern India, expecting to return to China during the summer. He is seeking to discover useful plants that may be grown in America. It is an interesting fact that Mr. Bryan Lathrop, of Chicago, who is responsible for these excursions, occupies the unique position of a man who is spending his money to assist his government in botanical work.

THE NATURALISTS of the central states at their recent meeting in Chicago determined to form a permanent organization, and a committee of five was appointed to suggest a plan of organization, to confer with a similar committee of the American Society of Naturalists regarding the relationship between the two societies, and to report at the next meeting of these organizations, which is to be held at Washington in January, 1903. The committee include two botanists, Dr. J. M. Coulter and Dr. William Trelease.

MR. ELAM BARTHOLOMEW, Stockton, Kansas, has assumed the editorship and publication of Ellis and Everhart's *Fungi Columbiani*. Every effort is promised to make this continued publication of high scientific value. There will be no "a," "b," and "c" packets, but a given species occurring on two or more hosts will in each subsequent issue constitute a new number. It will be considered allowable in some instances, in order to show ecological variation and geographical distribution, to reissue a species on the same host when it comes from widely separated regions. It is expected that two centuries will be issued each year, each issue being limited to seventy copies, and the subscription price being $6.00 a copy unless some previous contract has been made.

THE FOLLOWING persons have been appointed American editors of the reorganized *Botanisches Centralblatt:* D. H. Campbell, morphology; C. J. Chamberlain, cytology; D. T. MacDougal, physiology; G. T. Moore, algae; D. P. Penthallow, paleontology; H. von Schrenk, fungi; William Trelease, phanerogams. In order that the work of the American board of editors may

be properly coordinated Professor Trelease has been asked to act as chairman of the editorial board with the assistance of Dr. von Schrenk as general secretary. The central position of St. Louis and its excellent library and exchanges recommend it as the place most suitable for the editorial headquarters.

The British board of editors is as follows: Miss Edith Barton, algae; George Massee, fungi; Anthony Gepp, archegoniates; B. Daydon Jackson, phanerogams; J. Bretland Farmer, cytology; S. H. Vines, physiology; W. H. Lang, morphology, D. H. Scott, paleontology.

WE NOTE the following list of calls or promotions from the *American Naturalist:* DR. LUJO ADAMOVIC, known for his excellent work in phytogeography, to be professor of botany and director of the Botanical Garden at Belgrade; DR. A. H. R. BULLER to lecture in botany at the University of Birmingham; DR. FREDERIC E. CLEMENTS to an adjunct professorship in botany at the University of Nebraska; MR. GEORGE H. LYMAN to be professor of botany at Dartmouth College, in place of Dr. G. T. Moore, who is now with the Department of Agriculture; W. J. PALLADIN, the well-known physiologist, to be professor of physiology and plant anatomy at the University of St. Petersburg; MR. JOHN J. THORNBER, formerly associated with the Botanical Survey of Nebraska, to be professor of botany at the University of Arizona; DR. OSCAR UHLWORM, who has for so many years been associated with the *Botanisches Centralblatt*, to be librarian of the Royal Library, Berlin, also chief of the German Bureau for International Bibliography.

THE THIRD annual meeting of the botanists of the central states was held at the Hull Botanical Laboratory of the University of Chicago, December 31 to January 2, inclusive. Since there has been as yet no organization effected, there was no complete independent registration of the botanists. More than forty professional botanists, however, were present, and attendance at the sessions varied from fifty to eighty. Even during the last hours, when it was expected that many would have left the city, more than fifty were present. Among the institutions represented were the following: The University of Colorado, Francis Ramaley; the University of South Dakota, M. A. Brannon; the University of Minnesota, Conway MacMillan, H. L. Lyon; the University of Wisconsin, R. A. Harper, H. G. Timberlake, C. E. Allen; Beloit College, H. G. Densmore; State Normal School, Milwaukee, J. N. Mitchell; the University of Iowa, T. H. Macbride; Upper Iowa University, Bruce Fink; Parsons College, F. D. Heald; the University of Missouri, Charles Thom; Missouri Botanical Garden, William Trelease; University of Illinois, T. J. Burrill, C. F. Hottes; Illinois State Normal School, O. W. Caldwell; Illinois College, J. B. Overton; Blackburn University, Charles Robertson; Northwestern College, L. M. Umbach; University of Indiana, D. M. Mottier, C. A. King; Purdue University, Stanley Coulter; University of

Michigan, F. C. Newcombe, J. B. Pollock, H. S. Reed; Michigan Agricultural College, C. F. Wheeler; University of Ohio, E. E. Bogue; Oberlin College, F. O. Grover; Alabama Polytechnic Institute, E. M. Wilcox; Field Columbian Museum, C. F. Millspaugh; Northwestern School of Pharmacy, Albert Schneider; the University of Chicago, J. M. Coulter, C. R. Barnes, B. M. Davis, H. C. Cowles, B. E. Livingston, W. J. G. Land, H. N. Whitford, J. M. Westgate, C. D. Howe, G. H. Shull, F. M. Lyon, T. C. Frye, L. M. Snow, M. E. Mathews, G. E. Yocum, G. M. Holferty; E. B. Copeland, and unattached, E. J. Hill. The program of papers was very full. A list of these and abstracts, so far as furnished by the authors, will be published in *Science.* Thirty-two botanists participated in the annual dinner of the American Society of Naturalists at the Auditorium Hotel, Wednesday, January 1. The third report of the committee appointed by the Society for Plant Morphology and Physiology to secure better reviews of botanical literature was sent by the chairman of the committee to be presented simultaneously to the botanists of the central states. Printed copies were distributed and full verbal explanation of the plans regarding the new management of the *Botanisches Centralblatt* was made by Dr. Trelease. The meeting expressed its appreciation of the courtesy of its eastern confrères in sending copies of the report. On Thursday morning it was decided to form a permanent organization and a committee consisting of Messrs. Coulter, Mottier, and MacMillan was appointed to formulate plans for organization and to present them at the next meeting. It was voted that the next meeting of the central botanists should be held in Washington, D. C., in connection with the meeting of the American Association for the Advancement of Science and the American Society of Naturalists.

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NOTES ON THE GAMETOPHYTES AND EMBRYO OF PODOCARPUS.

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(WITH PLATES V–VII)

DURING a visit to Jamaica in the summer of 1900 I took advantage of the opportunity to make a collection of female cones of *Podocarpus coriacea* from trees cultivated in Castleton Garden. The climate of this part of the island, hot and wet, is apparently not congenial to this species, for it was afterward found that none of the ovules had been pollinated. This absence of pollen tubes, in connection with the fact that it was necessary to fix in alcohol, made the material of little value, and only a few of the figures are drawn from it.

Most of the results were obtained from collections made in June and July, 1901, from a male and a female tree grown in Darlington, South Carolina. The plants were small and scraggy, but both bore numerous cones, and, though they were separated by more than a hundred feet, over 95 per cent. of the ovules examined were furnished with pollen tubes. I cannot state positively that these trees are also *P. coriacea*, as there was no means of identifying them at the time, and I neglected to bring the vegetative parts to this country. However, as the fruits seem identical with those collected in Jamaica, it is probable that they are the same species.

It is unfortunate that the results here given are not more

complete, and they are published with the hope of supplementing them from future collections. The Darlington material was fixed at the tree in corrosive-acetic (aqueous solution of corrosive sublimate 95 parts, glacial acetic acid 5 parts), the prothallium being exposed at the sides or removed with the nucellus from the integuments. Sections 5 or 10 μ in thickness were made in paraffin, and in the case of the pollen stained in Haidenhain's iron-alum-haematoxylin or Flemming's triple. For prothallium and archegonium the latter stain was most used; while with embryos a combination of Delafield's haematoxylin and saffranin gave the best results.

Most of the work has been done in the Bonn laboratory, and I wish to express here my appreciation of the unfailing kindness of Professor Strasburger.

THE POLLEN SAC AND POLLEN GRAIN.

Two pollen sacs are borne on the lower surface of each sporophyll, as in the Abieteae, but they differ from these in being less sunken in the tissue and in their wider separation. The wall of the mature sac (*fig. 11*) consists of an outer layer of large cells whose walls are strengthened internally with thickened bands, and of three or four layers of thin cells which finally almost completely collapse. Within these is the one-layered tapetum, which disorganizes during the time that the pollen grains are undergoing their divisions. In *fig. 11* some of the tapetal cells are shown to contain two nuclei, which is often the case. It will be noticed that the microsporangium wall as here described is very like that of the Abieteae, while it differs from the generally two-layered wall found in the Cupresseae and Taxodium.[1]

In the development of the pollen the youngest stage found was after the separation of the tetrads, and before the first division of the grain. The wings have already reached their full size. All stages, from the uninucleate to the completely mature

[1] All references to Taxodium, unless otherwise stated, are taken from my unpublished paper on the gametophyte and embryo of Taxodium, a short preliminary account of which appeared in the *Johns Hopkins University Circular* 19:—. 1900.

pollen grain, were found in material collected from the same tree on a single day. This does not necessarily imply any unusual rapidity of development, for pollen was being shed from this tree for more than a week. As a matter of fact, however, the divisions in the grain, when once begun, follow each other in rapid succession, a fact also noted in the pollen of Pinus by Coulter and Chamberlain (1901). In the same cone undivided grains may be found at the top and three-celled ones at the base. It may be stated at once that there are three mitotic divisions in the pollen grain, forming two prothallial cells, a generative cell, and a tube nucleus. This noteworthy and rather unexpected behavior shows that in all essential points the pollen grains of Podocarpus and of the Abieteae are duplicates, and the peculiarities to be described below do not affect this fundamental agreement.

It is interesting to note here a prediction made by Schacht as long ago as 1860. He says: "Podocarpus, dessen männliche Blüthe den Abietineen entspricht, hat auch dieselbe Form des Blüthenstaubs, der wahrschleinlich in derselben Weise seinen Pollenschlauch entwickelt." The only other gymnosperm in which it is established that two prothallial cells are normally found in the pollen grain is Ginkgo, first figured by Schacht (1860). In *Ceratozamia longifolia* Jurányi (1870) found three small cells (presumably two prothallial and one generative) sometimes present in the pollen grain, although two was the commoner number. In all other Cycadales investigated only one prothallial cell has been found. Schacht found three small cells in the pollen of Ephedra, while Jurányi (1882) figures a varying number, in one case six nuclei being shown. In Taxus and the Cupresseae no prothallial cell has yet been discovered in the microspore, and there are none found in Taxodium.

During all of its divisions the pollen grain of Podocarpus is packed with starch (*figs. 1–6*), which disappears only just before the grain is shed. I know of no other gymnosperm in which this is the case. The first division is shown in *fig. 1*. A prothallial cell of the usual shape is cut off, but, as in other cases,

no cellulose wall is formed. The second division follows promptly, cutting off a similar cell (*fig. 2*), and a third gives rise to the generative cell and the tube nucleus (*fig. 3*). The spindles of all the divisions are much broader at the prothallial than at the opposite end, as figured by Coulter and Chamberlain (1901) for Pinus, and the chromosomes are very large in proportion to the spindle (*fig. 3*). Not infrequently this spindle of the third division was strongly inclined (*fig. 6*), and in such cases the generative cell may be placed in a distinctly excentric position.

The prothallial cells do not promptly degenerate as in the Abieteae, but the second, and sometimes the first also, behaves in a manner unknown in other conifers and only paralleled in Ginkgo and the Cycads. Both nuclei organize a coarse reticulum and a nucleolus, and increasing in size become as conspicuous as the generative nucleus (*figs. 3* and *4*).[2] They still remain flattened and elongated, but their size is such that with the generative cell they may occupy half the diameter of the pollen grain (*fig. 5*). So far the development of the two prothallial cells has been the same, but at this point their paths as a rule diverge. The cytoplasm of the second loses its individuality and becomes indistinguishable from that of the tube (or wall) cell, and its nucleus slips from its former position and lies free in the general cytoplasm. This history may be further complicated by the amitotic division of the nucleus before its liberation (*fig. 7*). In such cases the two nuclei generally slip out in different directions and place themselves on opposite sides of the generative cell (*figs. 8* and *10*). Cases were found, however, where both nuclei had moved out in the same direction and lay side by side (*fig. 9*). This was probably the result of an excentric position of the generative cell.

That the division just described is amitotic is proved by many connecting stages, and by the persistent absence of spindles.

[2] Coulter and Chamberlain (1901) figure both prothallial nuclei as developing a reticulum in *Pinus Laricio*, but this condition is shortly followed by rapid disintegration.

The nucleus before the completion of its division is often much drawn out and thin in the center, as if compressed between the cells above and below. In fact, as the second prothallial nucleus or nuclei move away, the generative cell sinks down and comes in contact with the first prothallial cell (*figs. 7* and *9*). It would be difficult to state the proportional number of cases in which the second prothallial nucleus divides; hundreds of such were found, and in my preparations they were probably as numerous as those in which the division had not occurred.

The first prothallial cell seldom develops further than the stage shown in *fig. 4*. It now begins to degenerate (*fig. 7*), but so slowly that even at the time of shedding it is still conspicuous (*fig. 8*). But while degeneration is the rule for this cell, not a few cases were found where, like the second, it had lost its individuality and liberated its nucleus in the general cavity (*fig. 10*). The nucleus here shows no sign of degeneration, but is apparently as healthy and active as its neighbors. In *fig. 9* two nuclei appear in the first prothallial cell. They are surrounded by dense protoplasm and it is not yet apparent whether they are to be liberated or are to degenerate. In undoubted cases of degeneration the nucleus is often found fragmented into three or more parts.

The generative cell is distinguishable in all cases by its protoplasmic sheath and the structure of its nucleus, which is always denser than any of the other free nuclei of the grain. By comparing the figures it will be seen that the prothallial nuclei after their liberation become much less dense and approach in structure the tube nucleus. They remain more dense, however, than the latter, and are further to be distinguished from it by their size and position.

The question now naturally arises, how much of this history as described is normal and how much is abnormal? The fact that the tree from which this pollen was taken was cultivated under unnatural conditions might lead us to expect abnormalities, and I am inclined to consider as such the fragmentation or liberation of the first prothallial nucleus. But the invariable persistence of

the second prothallial nucleus, whether fragmented or not, convinces me that this at least is normal, and that we have in Podocarpus a case analogous in this respect to Ginkgo and the Cycads. This view is further supported by the presence in the pollen tube, in the only three cases in which I was able to follow it throughout, of three small nuclei in addition to the body cell or its products. *Figs. 14* and *16*, sections from the same pollen tube, show a case of this kind. The absence of early stages in the sprouting of the pollen tube makes a distinction between prothallial and stalk nucleus difficult, but their positions favor the designations given in the figures. There can be little doubt as to the identity of the pollen-tube nucleus (*t n*, *fig. 16*).

Jurányi (1870) twice found two nuclei in the tip of the young pollen tube of *Ceratozamia longifolia*, but the doubling may have here resulted from the abnormal conditions, as the tubes were sprouted on ripe pears. Arnoldi (1900, *a*) figures an extra nucleus in the pollen tube of *Cephalotaxus Fortunei*, and very recently Miss Ferguson (1901, *a*) found two cases in which the pollen grain of *Pinus Laricio* still contained three nuclei after the tube nucleus had passed out. In the case of Pinus the most probable explanation seems to be that the extra nucleus is that of the second prothallial cell, as in Podocarpus.

Perhaps the persistence of one of the prothallial nuclei was once common in all conifers; an ancient character which, though now generally suppressed, may occasionally appear. It is of course possible that the particular plant of Podocarpus from which my results were obtained has a peculiar tendency to such a reversion, and that the peculiarities of its pollen are not characteristic for the species. Whether such is the case only future work can determine.

THE POLLEN TUBE.

On June 26, the date of the first collection, fertilization had already taken place in the majority of cases, and only a few undischarged pollen tubes were found. *Fig. 12* illustrates the body cell before its division, what is probably the stalk nucleus

lying in contact with it below. Another small nucleus was present in addition to the tube nucleus. In this case the pollen tube had reached the prothallium before the archegonia initials could be distinguished from their neighbors. I have found this to be also the case in both Taxodium and Taxus, when the pollen tubes reach the embryo-sac before the beginning of cell formation. In the Abieteae the tubes reach the archegonia only a few days before fertilization. On reaching the prothallium the pollen tube spreads out to an unusual extent. When only one is present it may cover almost the whole tip of the prothallium and send down short spurs on the sides.

Only two cases were found showing the male cells, but these leave no doubt that there is only one functional male cell formed, as in Taxus. *Figs. 13–16* are sections through the same pollen tube, *13–15* being serial. The male nucleus nearest the tip has appropriated all of the protoplasm, leaving the other thrust almost entirely out of the cell, and naked on its outer surface. The difference in the structure of the two nuclei is also marked. The functional one has the usual structure of the male nucleus in gymnosperms—a very dense, close-meshed linin reticulum, difficult to stain, which, except in very thin sections, almost hides the nucleolus. The latter is not shown in the figures, but appears in another section. In both Podocarpus and Taxodium I can confirm Miss Ferguson's (1901, *a*) statement that there is no metaplasmic substance in the male nuclei. An irregular nucleolus is always present. It is the only part of the nucleus that takes the saffranin stain, and this, together with its evidently compound nature and in Taxodium its behavior in fertilization, convinces me that it is composed of chromatin.

The extruded nucleus shown in *figs. 13* and *14* has apparently gone through the same developmental changes as the functional one, but the reticulum has now begun to coagulate, if the word may be used, into more or less separate clumps, and the evidences of degeneration are unmistakable.

The protoplasm of the male cell consists of a denser inner portion immediately surrounding the nucleus, and an outer sheath

which is not at all points sharply distinct from the protoplasm of the pollen tube (*fig. 16*). There is no starch. Goroschankin (1880)[3] found starch in the male cells of the Cupresseae, and Arnoldi (1900) found it in *Sequoia sempervirens*, Cryptomeria, and Taxodium. This I can confirm for Taxodium.

As already stated, the pollen tube was found to contain three nuclei in addition to the male cells.

THE FEMALE PROTHALLIUM.

The macrospore arises deep in the nucellus and is not surrounded by "spongy" tissue such as is found in the Abieteae, Cupresseae, and Taxodieae, and which has so often been erroneously described as of sporogenous character. Miss Ferguson's (1901, *b*) suggestion that the spongy tissue is active in nourishing the prothallium is probably correct; an interpretation I had arrived at from a study of Taxodium.

The youngest stage found is illustrated in *fig. 18*. The prothallium is in the four-celled stage, and at its tip two disorganizing cells are found, which are probably the undeveloped macrospores, but at this late stage it is not safe to draw any conclusion as to their origin. The prothallium is surrounded by cells of the ordinary vegetative type, the innermost of which are disorganizing. The disorganizing cells abut directly on the prothallium, which is not the case where a "spongy" tissue is present.

Stages showing cell formation were not found, but the straight rows of cells conspicuous in young prothallia show that the tissue arises in the usual way by ingrowing tubes. The central region first becomes firm, and in alcohol-fixed material this part remains extended, while the upper and lower buds may be much shrunken. At the time of fertilization the prothallium has reached about two-thirds or three-fourths its full size. *Fig. 21* shows the structure of the prothallium from axis to surface. In the center is a cylinder of very small cells extending from just below the archegonia to near the base. From this row outward the cells increase rapidly in size and become largest near the

[3] I have not seen this paper, but take the statement from Arnoldi (1900).

surface. The outer layer, however, is of an entirely different character. It is composed of very small, regular, epidermis-like cells with dense protoplasm, but almost free from the starch grains found abundantly in other parts. This layer is absent at the tip of the prothallium and is not quite so regular at the base. No such definite layer seems to have been described for other gymnosperms,[4] but in Taxus I have found the outer cells to approach these in character, though not so definitely arranged or so small proportionately. There is little doubt that these surface cells are specially modified for secretion, and it is worth noticing that when a spongy tissue is present there they are not found.

The larger cells of the prothallium, as is usual in conifers, contain many nuclei at the time the embryos are formed (*fig. 20*), while those on the surface have generally only one, or sometimes two.

In only one case were two prothallia found in one ovule (*fig. 19*). Neither had formed archegonia, although the seed had reached its full size. In one of them three or four tracheids were present (*fig. 20*). This will recall the formation of tracheids in the prothallia of ferns in cases of apogamy. In no other case of which I am aware have tracheids been described in the prothallium or endosperms of higher plants.

Hofmeister (1851) found two prothallia in the ovule of *Taxus baccata* and *Pinus silvestris*. He says (p. 127): "Es giebt Bäume von *Pinus silvestris* (ein solcher steht an einer sumpfigen Stelle des Leipziger botanischen Garten), welche, ähnlich der Eybe, in der Mehrzahl ihrer Eychen zwei Embryosäcke entwickeln."[5] Shaw (1896) and Arnoldi (1899) have found it the rule for a number of embryo sacs to be developed in *Sequoia sempervirens*, Arnoldi (1900, *b*) figures five in Cunninghamia, and I have once found two in Taxodium. The case of Gnetum is well known.

[4] Ikeno (1898) figures smaller and denser surface cells in Cycas, but they do not differ so sharply from the adjoining cells below as in Podocarpus.

[5] Farmer (Annals of Botany **6**: 213. 1892) in describing two prothallia in *Pinus silvestris* overlooks this previous discovery by Hofmeister.

THE ARCHEGONIA.

The number of archegonia varies from six or seven to about nine or ten. They are separated from each other by one or more layers of cells, and all open on the upper surface of the prothallium (*fig. 27*). In the youngest stage found, the neck cell was already cut off and had undergone a tangential division (*fig. 22*). In the mature archegonia the neck varies greatly, both in shape and the number of cells (*figs. 23–26*). In one case more than twenty-five cells were counted (*fig. 26*), or there may be only two (*fig. 23*). Perhaps the most common condition is three tiers of four cells each. Murrill (1900) has described considerable variation in the archegonium neck of Tsuga; and in Taxodium also there is much variation.

The jacket cells are not so dense as in many other conifers, and their nuclei do not go to pieces at the maturity of the archegonium, but still retain their shape and structure at the time of fertilization and after (*fig. 31*). Protoplasmic connections between the jacket cells and archegonia were not found, but they were not looked for by special methods, and may be present.

In the position and behavior of the ventral canal nucleus, Podocarpus agrees closely with Taxodium. No membrane is formed separating a ventral canal cell from the egg cell.[6] The nucleus is always closely pressed against the wall of the archegonium at first (*fig. 31*), and in this position it generally remains until the fertilization of the egg. Its position varies greatly. In *fig. 31* it is below the egg nucleus, but it may be placed opposite or above it, but always on the lateral wall and never directly under the neck cells. This retired position has probably been acquired to protect the ventral canal nucleus from harm during fertilization, for, as we shall see, it is to develop further. Both Strasburger (1879) and Belajeff (1893) figure the ventral canal nucleus of Juniperus in a lateral position.[7]

[6] Arnoldi (1900, *a*) emphasizes the absence of such a membrane in *Cephalotaxus Fortunei.*

[7] Arnoldi (1900, *b*) denies the presence of a ventral canal nucleus in Taxodium, Cryptomeria, Cunninghamia, and Sequoia, and even tries to throw doubt on its occur-

In archegonia which have reached maturity and failed to be fertilized the ventral canal nucleus frequently leaves its position at the surface and moves inward (*fig. 28*). It may even come in contact with the egg nucleus (*fig. 29*). Such cases might be interpreted as evidence in favor of the possible fertilization of the egg by the ventral canal nucleus, as suggested by Coulter and Chamberlain (1901, p. 98). In fact, however, the evidence is in the other direction, for though there is never any obstacle to the free approach of the ventral canal nucleus, and though it is often found very near the egg nucleus, or even in actual contact with it, in no case was an embryo found in an archegonium not provided with a pollen tube. In one case both the egg and ventral canal nuclei had divided amitotically into a large number of fragments, not half of which are shown in the figure (*fig. 30*).

In fertilized archegonia the ventral canal nucleus soon leaves its lateral position, increases in size, and frequently divides amitotically (*figs. 32, 34, 35, 50*). Its reticulum becomes denser and may approach that of the egg nucleus in character (*fig. 35*), as described by Chamberlain (1899) in *Pinus Laricio*. The division of the nucleus, its large size and healthy appearance, and its long persistence (*fig. 50*) leave little doubt that its function is to assist in nourishing the embryo. The persistence of the second male nucleus for a considerable time in the upper part of the archegonium has been described in a number of cases, and I am aware that my figures do not prove conclusively that the nuclei just described do not come from the pollen tube. Degenerating nuclei have been found near the pollen tube (*fig. 33*) which probably come from it, but in all such cases another nucleus was also present. This fact, together with the size, structure, and position of what has been called the ventral canal nucleus, convinces me of the correctness of my interpretation.

rence in the Cupresseae, although both Strasburger and Belajeff have given the spindles of the division in Juniperus. He is certainly mistaken so far as Taxodium is concerned, and I shall be greatly surprised if a ventral canal nucleus is not eventually found in all conifers.

The mature archegonium is shown in *fig. 31*. There are still vacuoles present towards the base, and a mass of kinoplasm completely surrounds the egg nucleus. In the center is another smaller dense area, and at the base a third appears. When the vacuole is nearer the center of the archegonium, only two kinoplasmic masses are present, one above and one below. The upper one does not always completely surround the nucleus, but is often only in contact with it at the side. As I have described these masses in some detail in Taxodium, and as they seem almost identical in the two genera, they need not detain us here.

At the tip of the egg cell just under the neck a collection of plastic material is figured. It stains red in saffranin and may easily be mistaken for a disorganizing ventral canal cell. It is generally present in both Podocarpus and Taxodium.

The pollen tube enters the neck, penetrates for some distance into the archegonium, and discharges its contents into the egg (*fig. 17*). The opening in the pollen tube is distinctly seen in *fig. 32*, where some of the protoplasm of the egg seems to have surged up through it after the discharge. The archegonium wall does not show the thickening around and below the neck characteristic of the Cupresseae (among which Taxodium must be placed), but is thin throughout and permits of much extension by the pollen tube (*figs. 32, 33*).

Strasburger (1892) has described the reduction of one male cell in Taxus and the Abieteae when the pollen tube fertilizes only one archegonium, and the recent work of Murrill (1900) and Miss Ferguson (1901, *a*) confirms this.[8] Where the archegonia are collected into complexes, the pollen tubes do not enter their necks, and both male cells are functional.

THE EMBRYO.

Fertilization stages were not found, but from *fig. 32* it seems probable that the fusion nucleus moves to the base of the archegonium before dividing, as in Juniperus (Strasburger, 1879), Taxus (Jäger, 1899), Taxodium,[9] Cryptomeria, and Sequoia

[8] Cephalotaxus (Arnoldi, 1900, *a*) is a possible exception.

[9] Noted for Taxodium in my preliminary paper, *l. c.*

(Arnoldi, 1900, *b*). The two nuclei here lie side by side, and are not surrounded by starch or furnished with so distinct a protoplasmic sheath as in the Cupresseae and Taxodieae. A denser and more granular area can be observed in immediate contact with the nuclei, but it is not sharply defined and fades imperceptibly in the general protoplasm of the archegonium. In *fig. 33* the second division has just occurred, and the nuclei, only two of which are shown, have not yet reached their full size. When the sixteen-celled stage is reached, the protoplasm of the embryo has become separated from the disorganizing area above (*fig. 34*). There is probably no further division before cell walls are formed, but the absence of important stages here leaves this point in doubt.

Fig. 38 shows the proembryo just as it is breaking through the base of the archegonium. It consists here, as invariably, of three tiers. First is a rosette of generally fourteen nuclei, which are separated from one another by cell walls, but are in open communication with the archegonium above; next come the suspensors, also usually fourteen in number, and below there is the large tip cell, with two nuclei not yet separated by a wall.

It will be noticed that the walls between the rosette nuclei seem to continue those separating the suspensors below. This is strong evidence that the rosette and the suspensors are established only after cell walls are formed, through the division of an originally single upper tier. It is in this way that they are formed in Taxodium. Between rosette and suspensors a thick cellulose plug is soon formed, a novelty, I believe, in the gymnosperm embryo (*figs. 38, 39, 41*). As the suspensors elongate, their nuclei, contrary to the rule, remain for some time at the archegonial end (*fig. 39*). This is probably connected with the deposition of the cellulose plug. The first division of the tip cell is longitudinal (*fig. 40*); and this is probably followed by another longitudinal wall in each cell, giving four tip cells in a tier. Such a stage was not found, but the frequent splitting of the proembryo into four parts suggests it. In *fig. 44* three embryos of such a group are shown, each at the tip of a single

suspensor. In *fig. 43* the three lower embryos have come, with one other, from a single archegonium, while the upper larger one is from another archegonium, in this case the suspensors not having separated. Fourteen suspensors appear in cross section in *fig. 36* and thirteen in *fig. 41*. As the proembryo penetrates further and further into the prothallium a number of the suspensors drop out at different levels, and cross sections just above the tip cells show a greatly reduced number (*fig. 37*). Jäger (1899) has described a similar behavior in Taxus. If the tip cells separate, each is usually furnished with a single suspensor (*figs. 43, 44*). Protoplasmic connections occur between the suspensor cells near the archegonium (*fig. 42*). Although the individual fibers were scarcely distinguishable, the appearance leaves no doubt of their presence.

The embryonal tubes may appear very early (*fig. 46*), but usually not before the stage shown in *fig. 48*. They are formed by the almost simultaneous elongation of all the cells on the proximal surface of the embryo, and by their growth force it deeper into the prothallium.

Various stages in the development of the embryo are given in *figs. 43–48*. If the suspensors do not separate, each of the four-tip cells generally divides first by a transverse wall; if they do separate, the first division of the single tip cell is generally longitudinal. Further than this no regularity is apparent.

A median longitudinal section of the oldest embryo found is given in *fig. 49*. There is no indication as yet as to where the root tip is to appear, and a distinction between dermatogen, periblem, and plerome has not arisen.

In one case an embryo was found which had grown directly upward and passed out between the prothallium and nucellus (*fig. 50*), where, bending sharply, it continued its course for some distance.

AFFINITIES OF PODOCARPUS.

In looking over the results of this paper, we find that Podocarpus agrees with the Abieteae in the gross structure of the

pollen grain (long known, of course), in the presence of two male prothallial cells, in the distribution and arrangement of the archegonia, in the reduction of the number of functional male nuclei to one (?), and in the penetration of the pollen-tube into the archegonium. The first three of these characters, at least, are of much taxonomic importance, as is shown by their constancy in the different groups. On the other hand, the structure and manner of formation of the proembryo, where points of difference appear, although constant, so far as known in the Abieteae,[10] are by no means so constant in other families, and are not of such value in classification.

When it is noted further that none of the characters of agreement mentioned are found in the Cupresseae, and few of them in any other conifers, it seems safe to conclude that in the Podocarpeae are to be found the nearest living relatives of the Abieteae.

SUMMARY.

1. The pollen grain contains two prothallial cells.

2. The second prothallial nucleus persists and is found later in the tip of the pollen tube. It may divide amitotically.

3. The mature pollen grain sometimes contains as many as six nuclei, probably abnormally.

4. The pollen tube reaches the prothallium before the archegonial initials can be distinguished. It contains no starch.

5. There is but one functional male cell formed.

6. There is no "spongy" tissue around the macrospore.

7. The prothallium is furnished with a distinct epidermis-like layer of small regular cells which are modified for secretion.

8. Two large prothallia were once found in the same ovule. One of them contained tracheids.

9. The archegonia vary from about seven to eleven, and all open on the micropylar end of the prothallium. The neck varies greatly in shape and number of cells. Two large kinoplasmic

[10] Only the interarchegonial development is referred to here. Many variations are recorded in its later history.

masses are generally present in the mature archegonium, one in contact with or surrounding the egg nucleus, the other near the base.

10. The ventral canal nucleus is not separated from the protoplasm of the egg by a membrane. It persists for some time after fertilization and probably assists in nourishing the embryo.

11. The pollen tube enters the archegonium to discharge its contents.

12. Four divisions of the fusion nucleus occur before cell walls are formed.

13. The proembryo consists of three tiers of cells, the upper two of fourteen each, the lower of one cell containing two nuclei.

14. A heavy cellulose plug is formed between the suspensors and the rosette.

15. The suspensors may separate and several embryos develop from one archegonium.

16. The Podocarpeae are considered as the nearest living relatives of the Abieteae.

BONN, GERMANY.

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EXPLANATION OF PLATES V–VII.

The figures, with the exception of *fig. 19*, were drawn with Leitz camera lucida, and reduced one-half by photography. The magnification given in each case is one-half that of the original drawing. Figures from *Podocarpus coriacea* are so designated. All others are from material collected in Darlington, S. C., from a species probably the same, but not certainly identified. The abbreviations used are: *b c*, body cell; *dn*, degenerating male nucleus; *en*, egg nucleus; *et*, embryonal tubes; *g*, generative cell; *mc*, male cell; p^1, 1st prothallial cell, or the two nuclei arising from the division of its nucleus; p^2, 2d prothallial cell, or the two nuclei arising from the division of its nucleus; *r*, rosette cells; *s*, suspensors; *stn*, stalk nucleus; *tn*, tube nucleus; *v n*, ventral canal nucleus, or group of nuclei arising from its division.

PLATE V.

FIG. 1. First division of pollen grain. × 1550.

FIG. 2. Second division of pollen grain. × 1550.

FIG. 3. Third division of pollen grain. × 1550.

FIG. 4. The same, later stage. × 1550.

FIG. 5. Pollen grain soon after third division; starch still present. ×750.

FIG. 6. Oblique spindle of third division. × 750.

FIG. 7. Pollen grain soon after the amitotic division of the second prothallial nucleus. × 1550.

FIG. 8. Five nuclei in pollen grain, two of which have arisen from the amitotic division of the second prothallial nucleus. × 750.

FIG. 9. Pollen grain with six nuclei; the first prothallial nucleus has also divided amitotically. × 750.

FIG. 10. Pollen grain with five nuclei, all of which are lying free in the general cytoplasm: the generative nucleus is furnished here, as always, with a special protoplasmic sheath. × 750.

FIG. 11. Section of wall of microsporangium just before the first division of the pollen grain. × 315.

FIG. 12. Body cell and stalk nucleus, after the pollen tube has reached the prothallium. × 315.

FIGS. 13-16. Sections through the same pollen tube, showing functional male cell, degenerating male nucleus, and three small nuclei; *figs. 13, 14,* and *15* are consecutive. × 315.

FIG. 17. Diagram showing pollen tube from which the above figures mere made; other pollen tubes and a fertilized archegonium are also shown. × 30.

FIG. 18. Four-celled female prothallium with two disorganizing microspores at tip. × 150. *P. coriacea.*

FIG. 19. Diagram of two mature prothallia in the same nucleus; the cross indicates the position of the tracheids. × 4½. *P. coriacea.*

FIG. 20. Tracheids found in one of the prothallia represented in the above diagram; they are surrounded by multinucleate cells of the usual type. × 150. *P. coriacea.*

PLATE VI.

FIG. 21. Median longitudinal section of prothallium from center to surface, showing small cells of the axial rows, and a single layer of small epidermis-like surface cells. × 30.

FIG. 22. Young archegonium; neck cell shows a cross division. × 150. *P. coriacea.*

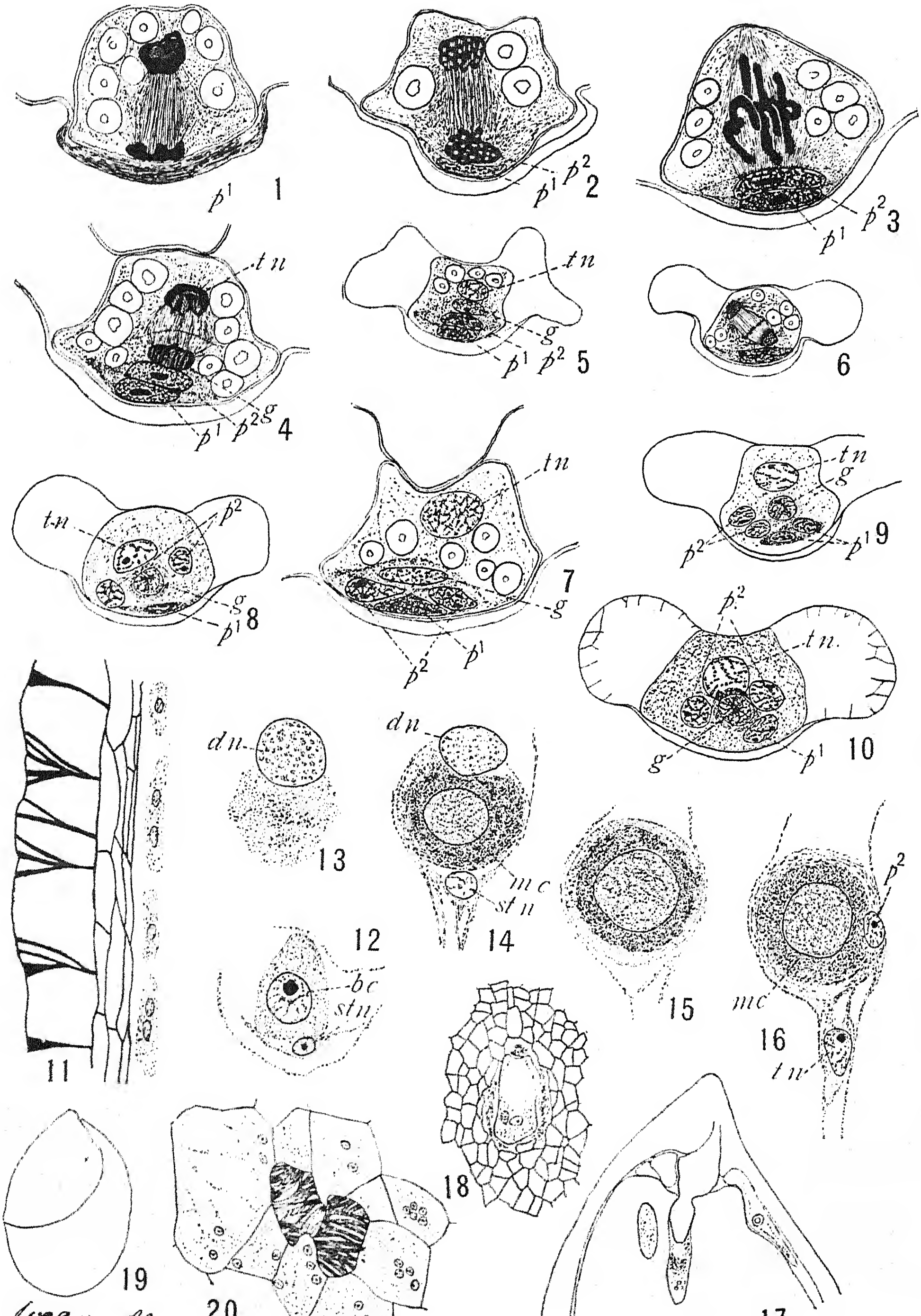
FIGS. 23-26. Neck cells of mature archegonia, showing great variation. × 150.

FIG. 27. Diagram of tip of ovule; archegonia mature. × 30.

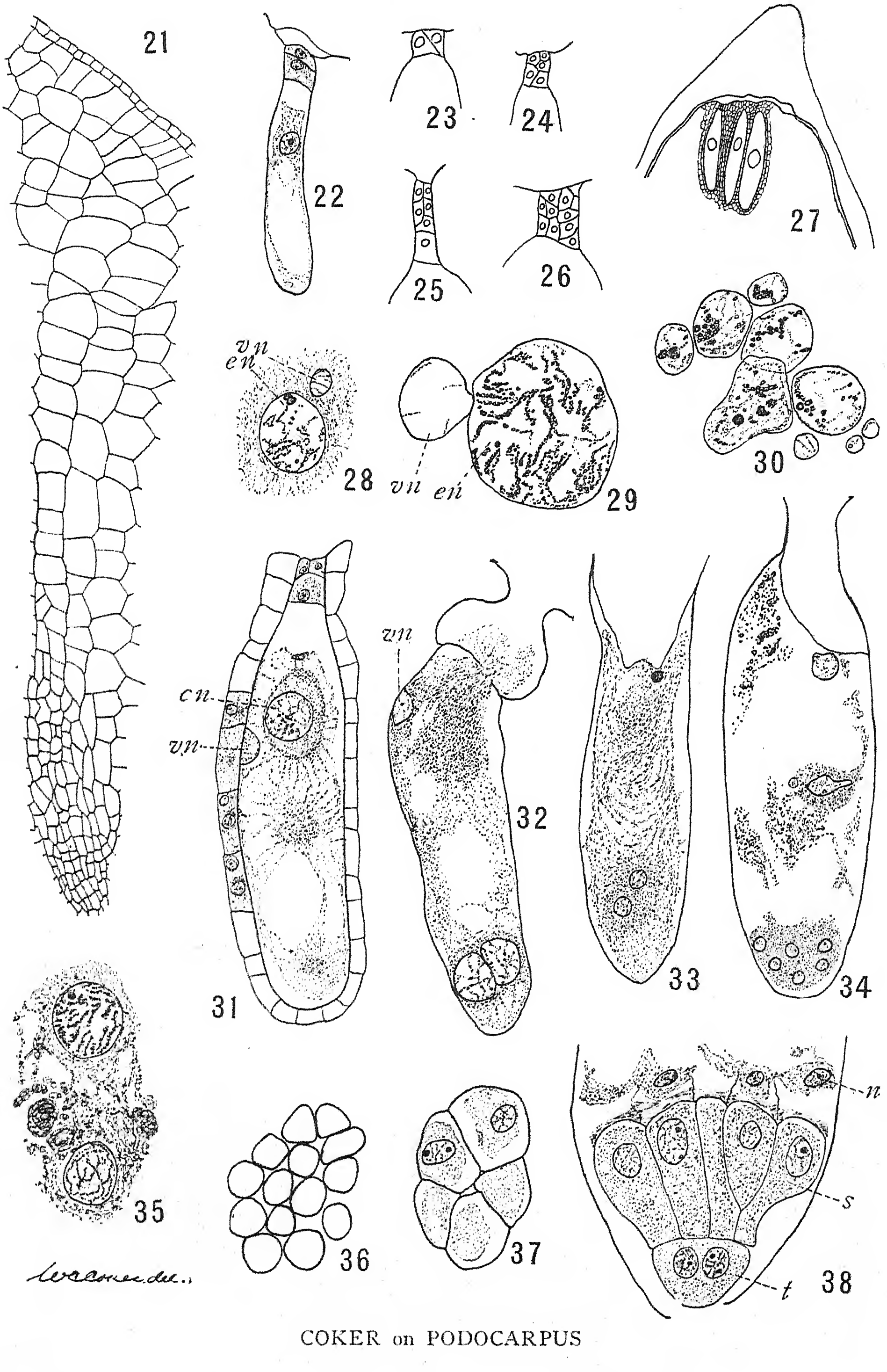
FIG. 28. Egg nucleus and ventral canal nucleus in mature archegonium. × 150.

FIG. 29. Egg nucleus and ventral canal nucleus in contact. × 315.

FIG. 30. Numerous nuclei which have arisen from amitotic division of the egg and ventral canal nuclei in the tip of the archegonium. × 315.



COKER on PODOCARPUS



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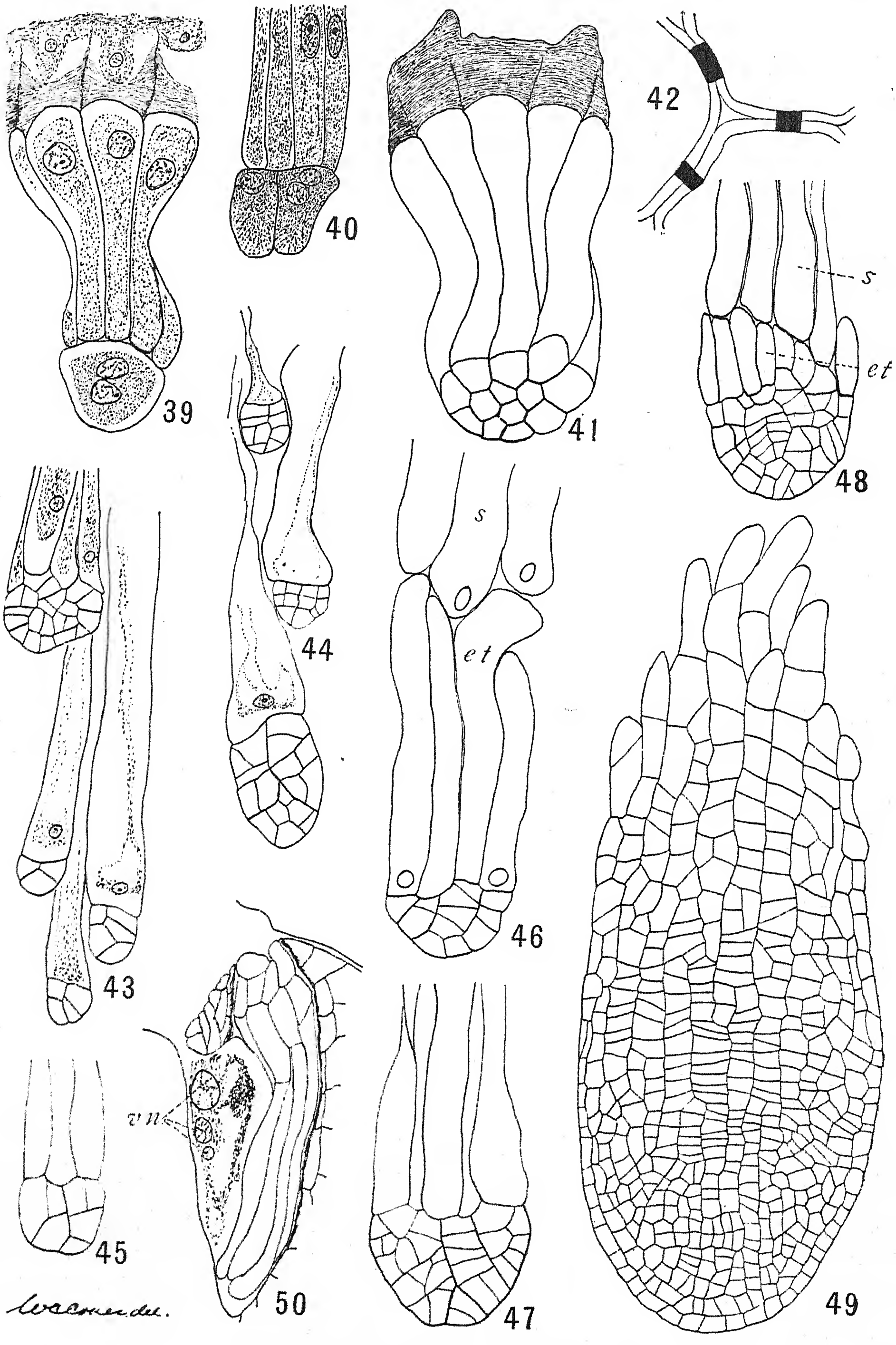


COKER on PODOCARPUS

FIG. 31. Mature archegonium; ventral canal nucleus pressed against the wall below the egg nucleus; three kinoplasmic masses present, one surrounding the egg nucleus; at the tip is a collection of plastic material. × 150.

FIG. 32. Two-celled embryo in base of archegonium; ventral canal nucleus above. × 150.

FIG. 33. Four-celled embryo; pollen tube still visible above, with a nucleus near its tip. × 150.

FIG. 34. Sixteen-celled embryo; several nuclei in the disorganizing cytoplasm above. × 150.

FIG. 35. Two nuclei in tip of an archegonium in the base of which is an embryo in the stage shown in *fig. 38*. × 315.

FIG. 36. Cross section of a group of fourteen suspensors. × 315.

FIG. 37. Cross section of a group of five suspensors just above the tip cells. × 315.

PLATE VII.

FIG. 38. Young embryo breaking out of archegonium. × 315.

FIG. 39. Slightly older embryo; two nuclei in one tip cell. × 315.

FIG. 40. Still older embryo, with two tip cells, one of which contains two nuclei. × 315.

FIG. 41. A group of thirteen suspensors; at their archegonial end is the thick cellulose plug. × 315.

FIG. 42. Protoplasmic connections between adjoining suspensors of a group. × 1550.

FIG. 43. A group of embryos from two archegonia. × 150.

FIG. 44. Another group of embryos from a single archegonium. × 150.

FIG. 45. Young embryo before development of embryonal tubes. × 150.

FIG. 46. Embryonal tubes, developed unusually early. × 150.

FIG. 47. Embryo just before formation of embryonal tubes. × 150.

FIG. 48. Origin of embryonal tubes. × 150.

FIG. 49. Older embryo. × 150.

FIG. 50. Abnormal embryo, growing upwards and passing between prothallium and nucellus. × 150.

NEW OR LITTLE KNOWN NORTH AMERICAN TREES. IV.

CHARLES S. SARGENT.

Prunus (PRUNOPHORA) **tarda,** n. sp.—Leaves convolute in vernation, oblong to obovate, acute, or acuminate and short-pointed at the apex, gradually narrowed and rounded or cuneate at the base, finely serrate, with straight or incurved teeth tipped with minute dark glands, cinereo-tomentose as they unfold, at maturity thick and firm in texture, dull yellow-green and glabrous on the upper surface, pale and pubescent or puberulous on the lower surface along the prominent yellow midribs and primary veins, 1½–3 in. long, ¾–1¼ in. wide; petioles stout, tomentose, ⅓ to ½ in. long, biglandular at the apex, with prominent dark stalked, often deciduous, glands, or eglandular; stipules acicular, ⅓ in. long, caducous. Flowers in 2 or 3-flowered subsessile umbels; pedicels slender, glabrous, ⅝ to ¾ in. long; calyx-tube narrowly obconic, glabrous toward the base, villose above, the lobes acute, entire, villose on the outer surface, coated within with thick, hoary tomentum; petals oblong-obovate, gradually narrowed below, short-clawed; filaments and pistil glabrous. Fruit short-oblong to subglobose, yellow, purple, red, dark blue, or black, ⅓ to ½ in. in diameter, acidulous; stone slightly compressed, obscurely ridged on the ventral suture, only slightly grooved on the dorsal suture, rugose, acute and apiculate at the apex, rounded at the base, ⅓ to ½ in. long.

A tree 20 to 25 feet in height with a trunk 18 or 20 in. in diameter, stout wide-spreading branches, slender, lustrous, light red-brown branchlets marked by occasional dark lenticels, and minute, acuminate, chestnut-brown buds. The bark of the trunk is light brown tinged with red, ½ to ⅝ in. thick, divided by shallow, interrupted fissures into flat ridges broken on the surface into small, loose, plate-like scales, and hardly distinguishable from that of *Castanea pumila* growing with it.

Flowers early in April. Fruit ripens late in October and November.

Glades and open woods near Marshall, Texas, in dry, gravelly soil, to western Louisiana and southern Arkansas. First noticed at Marshall on April 19, 1901, by *William M. Canby*, *B. F. Bush*, and *C. S. Sargent.*

Well distinguished from *Prunus umbellata*, with which perhaps it may have been confounded, by its remarkable bark, which differs from that of all American plum trees, and by its variously colored, very late-ripening fruit.

Crataegus Bushii, n. sp.—Leaves obovate, broad and rounded or acute at the apex, to elliptical, gradually narrowed, cuneate, and entire below the middle, coarsely serrate above, with straight gland-tipped teeth; when they unfold, green above, pale below, villose, with short white hairs on both sides of the midribs and veins; nearly fully grown when the flowers open, and then dark green and lustrous on the upper surface, slightly villose on the upper side of the midribs; at maturity coriaceous, very lustrous, 1¼ to 1½ in. long, ½ to 1 in. wide, with stout midribs deeply impressed above, and few slender prominent primary veins; on vigorous leading shoots usually elliptical, acute, coarsely serrate, frequently 3 in. long and 1½ in. wide; petioles stout, grooved, margined above, at first villose, finally glabrous, usually about ½ in. long; stipules linear-lanceolate or oblanceolate, glandular-serrate or entire, ¼ in. long, caducous. Flowers from ¾ to 1 in. in diameter in broad, compound, many-flowered, glabrous corymbs; bracts and bractlets linear, entire, caducous; calyx-tube broadly obconic, glabrous, the lobes elongated, linear-lanceolate, entire or occasionally slightly dentate, reflexed after anthesis; stamens 20; anthers large, bright rose-color; styles 2 or 3, surrounded at the base by conspicuous tufts of pale hairs. Fruit on slender peduncles in few-fruited drooping clusters, oblong, green tinged with dull red, ⅓ in. long; calyx-cavity broad and shallow, the lobes only slightly enlarged, erect and incurved, mostly deciduous before the ripening of the fruit; flesh thin, green, dry, and hard; nutlets 2 or 3, broad, prominently ridged on the back, ¼ in. long.

A tree 15 to 20 feet in height with a trunk 8 or 10 in. in diameter, covered with dark red-brown, fissured bark broken into small, closely appressed scales, small, spreading branches forming a broad, irregular, open

head, slender nearly straight glabrous branchlets, orange-green when they first appear, bright red-brown, lustrous, and marked by occasional oblong pale lenticels during their first summer, and dull gray-brown in their second year, and unarmed or sparingly armed with stout straight spines 1½ to 1¾ in. long.

Flowers about the 20th of April. Fruit ripens late in October or in November.

Fulton, Arkansas, in rich upland woods, *B. F. Bush*, April 4, 1900, April and October 1901.

The large and abundant flowers of *Crataegus Bushii*, with their pure white petals and large rose-colored anthers, and its dark lustrous leaves, make this species one of the most beautiful of the thorns of the Crus-galli section. From *Crataegus Crus-galli* of Linnaeus it differs in the number of stamens, in the smaller green fruit, in the presence of hairs on the young leaves, and in the absence or infrequency of spines.

Crataegus edita, n. sp.—Leaves oblong-obovate to oval, acute or acuminate at the gradually narrowed apex, gradually narrowed and cuneate at the entire base, coarsely and often doubly serrate above, with glandular teeth; when the flowers open dark green, lustrous and scabrate above with short rigid pale hairs, and pubescent or puberulous below particularly on the slender midribs and remote slightly raised primary veins; at maturity coriaceous, dark green, lustrous and slightly roughened on the upper surface, pale yellow-green and scabrate on the lower surface, 1½ to 2 in. long, ½ to 1 in. wide, or on vigorous shoots often slightly lobed, more coarsely serrate, 3 in. long, 1½ in. wide; petioles stout, winged above, villose, ultimately pubescent; stipules linear, glandular-serrate, villose, caducous. Flowers ½ to ⅔ in. in diameter in slightly villose few-flowered slender-branched compound narrow corymbs; bracts and bractlets linear, glandular, caducous; calyx-tube narrowly obconic, glabrous or slightly villose below, the lobes linear-lanceolate, entire, obscurely glandular-serrate, glabrous on the outer surface, puberulous on the inner surface, reflexed after anthesis; stamens 20; anthers small, rose-colored; styles 2 or 3. Fruit on stout glabrous or slightly villose peduncles, in few-fruited drooping clusters, short-oblong, full and rounded at the ends, slightly pruinose, dull green tinged with red, ¼ to ⅓ in. long;

calyx-tube prominent, with a broad deep cavity and elongated spreading lobes puberulous on the inner surface; flesh thin, green, dry and hard; nutlets 2 or 3, broad, prominently ridged with broad low ridges, light brown, ¼ in. long.

A tree in low moist ground sometimes 40 feet in height with a trunk a foot in diameter free of branches for 18 or 20 feet and covered with dark fissured scaly bark, stout wide-spreading branches forming a broad symmetrical flat-topped head, and slender nearly straight branchlets marked by numerous dark oblong lenticels, orange-brown and villose when they first appear, dull red-brown and often slightly villose during their second season, becoming light dull gray-brown the following year, and armed with stout straight chestnut-brown ultimately dull gray spines 1 to 2 in. long.

Marshall, Texas, common in low wet woods and on dry hills, *W. M. Canby, B. F. Bush*, and *C. S. Sargent*, April 19, 1901; Shreveport, Louisiana, *W. M. Canby, B. F. Bush*, and *C. S. Sargent*, April 21, 1901; Opalusas, Louisiana, *C. S. Sargent*, March, 1900, in bud only.

Crataegus edita belongs to the small group of Crus-galli-like species represented by *Crataegus berberifolia*, from which it differs in its less tomentose lustrous thicker scabrate leaves which are gradually narrowed and acute and not rounded at the broad apex, by its slightly villose not tomentose cymes and calyx, and by its smaller later-ripening dry green fruit. That of *Crataegus berberifolia* is nearly globose and bright orange color with a bright red cheek.

Crataegus fecunda, n. sp.—Leaves oblong-obovate to oval or broadly ovate, acute or rarely rounded and short-pointed at the apex, gradually or abruptly narrowed below, coarsely and usually doubly serrate, with broad spreading glandular teeth except toward the entire obscurely ciliate base; when the flowers open dark green, lustrous and scabrate on the upper surface with short pale appressed caducous hairs, and pale yellow-green and villose on the lower surface along the midribs and primary veins, with occasional white hairs; at maturity thin but firm, glabrous, dark green and very lustrous above, pale yellow-green below, 2 to 2½ in. long, 1½ to 2 in. wide, with stout midribs and remote primary veins only slightly impressed on the upper surface and after midsummer frequently bright red below; on leading shoots often slightly lobed, usually more or less convex by the drooping sides, 3 to 4 in. long, 2 to 3 in. wide; petioles stout, more or less winged above, grooved on the upper side, villose, often

glandular with scattered dark glands, glabrous and red at maturity, ½ to ¾ in. long; stipules linear to semi-lunate, and stipitate, coarsely glandular-serrate, ½ to ¾ in. long. Flowers ¾ in. in diameter in broad open many-flowered compound slightly villose corymbs; bracts and bractlets linear to oblong-obovate, coarsely glandular-serrate; calyx-tube narrowly obconic, more or less villose, the lobes elongated, acuminate, irregularly glandular-serrate, with stipitate dark red glands, villose on the inner surface, spreading after anthesis; stamens usually 10, occasionally 12 to 15; anthers small, dark purple; styles 2 or 3. Fruit on slender peduncles often ½ in. long, in broad drooping many-fruited glabrous clusters, short-oblong to subglobose, full and rounded at the ends, until nearly fully grown covered with long soft pale scattered hairs, at maturity dull orange-red, marked by numerous small dark lenticels, ⅞ to 1 in. long; calyx-cavity deep, comparatively narrow, the lobes linear-lanceolate, erect and incurved, coarsely glandular-serrate above the middle, dark red at the base on the upper surface; flesh remarkably thick, firm and hard, pale green, dry and sweet; nutlets 2 or 3, comparatively small, light-colored, rounded and obscurely ridged on the back, ⅓ in. long.

A tree 20 to 25 feet in height with a trunk 10 or 12 in. in diameter, covered with dark red-brown bark broken into small closely appressed scales, wide-spreading branches forming a broad symmetrical round-topped rather open head, and stout slightly zigzag branchlets marked by large pale oblong lenticels, dark green and lustrous and covered with soft matted pale hairs when they first appear, glabrous, lustrous and light orange-green during their first summer, and ashy gray in their second season, and armed with numerous very slender straight or slightly curved chestnut-brown shining spines 2 to 2½ in. in length.

Flowers near St. Louis toward the end of May and in the Arnold Arboretum during the first week in June. Fruit ripens and begins to fall toward the end of October, when the leaves assume brilliant shades of orange and scarlet or are often of a deep rich bronze color.

Rich woodlands, Allenton, Missouri, October, 1882, and Illinois bottoms opposite St. Louis, May, 1883, *George W. Letterman*.

Cultivated for many years in the Arnold Arboretum where it was raised from seeds collected by Mr. Letterman and where it now flowers and ripens its fruit.

Crataegus fecunda appears to be related to the *Crataegus elliptica* of Aiton but not of later authors, and to a group of species or varieties cultivated in Europe as *Crataegus Crus-galli splendens*, *Crataegus ovalifolia*, and *Crataegus prunifolia*, forms, although evidently of American origin, which are not now known to grow naturally in the United States. From these *Crataegus fecunda* differs in its thinner, larger, usually more acute and more coarsely dentate leaves, in its slightly villose not tomentose cymes, in the form, color and texture of the fruit, in the color of the young branches and in its more slender and more scattered spines.

Crataegus Georgiana, n. sp.—Leaves ovate, acute, or acuminate at the apex, full and rounded or broadly cuneate at the base, finely and often doubly serrate, with straight or incurved gland-tipped teeth, and slightly lobed with numerous short acute lateral lobes; as they unfold bronze-yellow and glabrous with the exception of a few caducous hairs on the upper surface; nearly half grown when the flowers open and then thin, dark yellow-green above and pale below; at maturity thin but firm in texture, dark blue-green on the upper surface, pale on the lower surface, 1½ to 2 in. long, 1 to 1¼ in. wide, with slender yellow midribs and three or four pairs of primary veins only slightly impressed above; on vigorous leading shoots often 3 in. long and 2 in. wide, sometimes deltoid and usually more deeply lobed than the leaves of lateral branchlets; petioles slender, grooved, often short-winged at the apex by the abruptly decurrent bases of the leaf-blades, usually about ¾ in. long; stipules linear-lanceolate, finely glandular-serrate, more or less deeply-tinged with red, ½ to ¾ in. long, caducous. Flowers ¾ in. in diameter on slender pedicels in usually 5–7-flowered compact thin-branched compound corymbs; bracts and bractlets linear, glandular, turning red in drying; calyx-tube broadly obconic, the lobes gradually narrowed from broad bases, acuminate, entire, obscurely and irregularly serrate; stamens 20; anthers small, bright rose-color; styles 5, surrounded at the base by a thin ring of pale tomentum. Fruit on slender peduncles, in few-fruited drooping clusters, full and rounded at the ends, often obscurely 5-angled, dull russet green, ⅜ to ½ in. long; calyx-lobes only slightly enlarged, mostly deciduous before the fruit falls, leaving a well defined

ring at the summit of the short calyx-tube; flesh very thin, light green, dry and hard; nutlets thin, rounded, irregularly grooved on the back, about ¼ in. long.

A tree 25 to 30 feet in height with a tall trunk 10 or 12 in. in diameter, covered with dark red-brown scaly bark, stout wide-spreading branches, forming a broad symmetrical round-topped head, and slender, straight, or somewhat zigzag branchlets marked by occasional small, pale lenticels, dark green tinged with red when they first appear, becoming dull reddish-brown during their first season, and gray or light reddish-brown during their second year, and armed with straight or slightly curved, slender, bright chestnut-brown, lustrous spines, rarely more than 1½ in. in length.

Flowers about the 20th of April. Fruit ripens and falls early in October.

Low meadows, in rich moist soil near Rome, Georgia; not rare. *W. M. Canby* and *C. S. Sargent*, May 6, 1899; *C. S. Sargent*, April 22 and October 7, 1900.

Crataegus sordida, n. sp.—Leaves rhomboidal, acute, or obovate, and rarely rounded at the apex, gradually narrowed from near the middle and cuneate at the entire base, serrate above, with slender, straight, or incurved glandular teeth, and occasionally irregularly divided above the middle into short, broad, acute lobes; about half-grown when the flowers open, and then membranaceous, lustrous, glabrous with the exception of a few scattered caducous hairs on the upper surface; at maturity subcoriaceous, dark green and lustrous above, pale below, about 1½ in. long and 1¼ in. wide; on leading shoots often oblong-obovate to oval, coarsely dentate and generally divided above the middle into 1 or 2 pairs of short lobes, 3 to 4 in. long, 2 to 2½ in. wide; petioles stout, glandular, more or less winged toward the apex, at first villose but soon glabrous, ½ in. long, often bright red in the autumn; stipules linear, acuminate, glandular, with minute red glands, caducous. Flowers 1 to 1¼ in. in diameter, fragrant, in few-flowered, compact, compound, slightly villose corymbs; bracts and bractlets linear, glandular-serrate, caducous; calyx-tube narrowly obconic, glabrous, the lobes narrow, acuminate, villose on the inner surface, reflexed after anthesis; petals dull, dirty white; stamens 20; anthers small, rose-color; styles 2 or 3, surrounded at the base by a

narrow margin of pale hairs. Fruit on slender peduncles in few-fruited drooping glabrous clusters, dark dull red, ⅓ to ½ in. in diameter; calyx prominent, with a broad shallow cavity and elongated, coarsely serrate, appressed or incurved lobes; flesh thin, yellow, dry and mealy; nutlets 2 or 3, broad, rounded, and ridged on the back with low wide ridges, ¼ in. long.

A slender tree, 20 to 25 feet in height, with a tall stem 5 or 6 in. in diameter, covered with dark furrowed and scaly bark, and often armed with long-branched spines, ascending branches forming a narrow oval head, and slender, nearly straight, branchlets, dark orange-green and villose when they first appear, marked by large, oblong, pale lenticels. becoming glabrous and bright chestnut-brown in their second season, and dull reddish-brown the following year, and armed with numerous slender, nearly straight, bright chestnut-brown lustrous spines 1 to 2½ in. long.

Flowers during the first week in May. Fruit ripens about the middle of September and soon falls.

Low woods and the gravelly banks of small streams, Ripley county, southeastern Missouri, *B. F. Bush*, Monteer, July 26, 1899, Pleasant Grove, August 8, 1899; *C. S. Sargent*, Pleasant Grove, September 30, 1900; *B. F. Bush*, Pleasant Grove, May 7, and Grandin, May 8, 1901.

Probably best associated with *Crataegus collina* of Chapman, *Crataegus sordida* differs from that species in its ascending, not wide-spreading, branches, by the much larger later fragrant flowers, which have narrow glabrous calyx-tubes, dull dirty white petals, rose-colored anthers, and 2 or 3 styles, while in the flowers of *Crataegus collina* the calyx-tube is broadly obconic and tomentose or villose, the petals pure white, the anthers yellow, and the styles 5 in number.

Crataegus sera, n. sp.—Leaves oblong-ovate, acute, rounded, truncate or slightly cordate, particularly on vigorous shoots at the broad base, irregularly divided into four or five pairs of short acute lateral lobes, sharply and sometimes doubly serrate nearly to the petiole, with straight glandular teeth; unfolding with the opening of the flowers and then pubescent above and coated below with thick hoary tomentum; at maturity membranaceous, dark yellow-green and glabrous on the upper surface, tomentose on the lower surface, 3 to 4 in. long, 2½ to 3 in. wide, with slender midribs slightly impressed above and thin remote primary veins extending to the points of the lobes; petioles slender, at first tomentose, ultimately pubescent, 1 to

1 ½ in. long; stipules linear, acuminate, glandular-serrate, villose, ¼ in. long, caducous; or on vigorous shoots lunate, abruptly acuminate, ½ in. long. Flowers ¾ in. in diameter, in compact compound many-flowered tomentose corymbs; bracts and bractlets lanceolate or oblanceolate, coarsely glandular-serrate, villose or tomentose, conspicuous, caducous; calyx-tube broadly obconic, coated with long matted pale hairs, the lobes broad, acute or acuminate, glandular-serrate, with large dark glands, tomentose on the outer surface, villose on the inner surface; stamens 20; anthers pale yellow; styles 4 or usually 5. Fruit on puberulous peduncles in drooping few-fruited clusters, obovate to oblong, dull dark red, marked by small pale lenticels, usually slightly villose or puberulous at the ends, about ⅔ in. long and ½ in. wide; calyx-cavity broad and shallow, the lobes enlarged, conspicuously glandular-serrate, erect and incurved, often deciduous before the ripening of the fruit; flesh thick, yellow, dry, and mealy; nutlets 4 or usually 5, thin, light brown, irregularly grooved on the back, with broad shallow grooves, ¼ in. long.

A tree 30 to 40 feet in height with a tall straight trunk 12 to 18 inches in diameter covered with pale slightly furrowed bark, thick branches forming a broad round-topped symmetrical head, and slender slightly zigzag branchlets marked by small oblong pale lenticels, coated when they first appear with dense hoary tomentum, light red-brown and puberulous during their first season and ultimately pale orange-brown, mostly unarmed or armed with occasional straight or slightly curved bright chestnut-brown spines 1 ¼ to 1 ½ in. long.

Flowers during the first week of May. Fruit ripens early in October. Low moist soil in the neighborhood of streams.

Belle Isle, in the Detroit river, Michigan, *C. S. Sargent*, May 23, 1899, September 25, 1901; woods adjacent to the Calumet river near Calumet, Illinois, *E. J. Hill*, May and September 1896 and 1897, May 1900; *C. S. Sargent*, September 29, 1901.

Probably often confounded with *Crataegus mollis* of Scheele, *Crataegus sera* will perhaps be found to be a common tree in southern Michigan, northern Indiana, and in northern and central Illinois. It may be distinguished from *Crataegus mollis* by its much thinner more oblong and rarely cordate leaves, by its smaller flowers, and smaller much later-ripening usually obovate fruit, the fruit of *Crataegus mollis* mostly falling toward the end of August or early in September.

Crataegus corusca, n. sp.— Leaves ovate, acute, truncate, rounded or slightly cordate at the broad base, irregularly divided into 4 or 5 pairs of short acute lateral lobes, doubly serrate with straight slender glandular teeth; in early spring coated above with short soft pale hairs and glabrous below; at maturity thin but firm in texture, glabrous, dark yellow-green and very bright and shining on the upper surface, pale yellow-green on the lower surface, 2 to 2½ in. long and wide, with slender pale midribs and primary veins only slightly impressed above; on vigorous leading shoots 3½ to 4 in. long and 3 in. wide, often deeply divided into narrow acute lobes; petioles slender, nearly terete, slightly glandular, at first villose, ultimately glabrous and dark red below the middle, 1¼ to 1½ in. long; stipules narrowly obovate, acute, glandular-serrate; on leading shoots lunate, coarsely dentate, ½ to ¾ in. wide. Flowers ¾ in. in diameter, in compact compound many-flowered corymbs coated with matted white hairs; bracts and bractlets linear-lanceolate, glandular-serrate; calyx-tube broadly obconic, glabrous, or villose below, the lobes acute from broad bases, coarsely glandular-serrate, villose on the inner surface; stamens 20; anthers small, pale pink; styles 4 or 5. Fruit in few-fruited drooping glabrous clusters on stout peduncles, ¾ to nearly 1 in. long, oblong to obovate, bright cherry-red, lustrous and marked by scattered dark lenticels, ⅝ to ¾ in. long, ½ to ⅝ in. wide; calyx-cavity deep, comparatively narrow, the lobes gradually narrowed and acute, slightly glandular-serrate, usually deciduous before the ripening of the fruit; flesh thick, yellow, dry and mealy; nutlets 4 or 5, dark-colored, rounded on the back, ¼ in. long.

A tree 18 or 20 feet in height with a tall trunk 8 or 10 in. in diameter, wide-spreading branches forming a handsome symmetrical head, and stout branchlets marked by numerous minute pale lenticels, dark green and villose when they first appear, becoming bright red during their first summer and light orange-brown and very lustrous during their second year, and armed with stout nearly straight bright chestnut-brown spines often 3 in. long.

Flowers the middle of May. Fruit ripens and begins to fall about the 20th of September, continuing to fall gradually until the end of October.

Sandy shores of Lake Zurich, Lake county, Illinois, *E. J. Hill*, September, 1899; *E. J. Hill* and *C. S. Sargent*, September, 1900; *E. J. Hill*, May, 1901.

Crataegus corusca is perhaps best associated with the *mollis* group, although it differs from the other species of that group which are now known in its firm and very bright and shining leaves and in the absence of tomentum from their lower surface even when young. The flowers, too, are unusually small for a species of that group.

Crataegus Ellwangeriana, n. sp.—Leaves oval, acute, full and rounded or broadly cuneate at the base, irregularly divided usually only above the middle into numerous short acute lobes, coarsely and often doubly serrate, with straight or incurved glandular teeth; in early spring roughened above with short pale hairs and villose below along the slender midribs and primary veins; at maturity membranaceous, dark green and scabrate on the upper surface, pale and nearly glabrous on the lower surface, 2½ to 3½ in. long, 2 to 3 in. wide; petioles slender, nearly terete, at first villose, ultimately nearly glabrous, 1½ to 2 in. long; stipules oblong-obovate, acute, villose, coarsely glandular-serrate, often ½ in. long, those of the upper leaves of fertile branches usually persistent until after the ripening of the fruit. Flowers 1 in. in diameter, on short stout pedicels, in compact compound many-flowered corymbs coated with matted pale hairs; bracts and bractlets lanceolate, coarsely glandular-serrate; calyx-tube broadly obconic, villose, the lobes elongated, lanceolate, glandular, with small pale stipitate glands, villose; stamens 8–10; anthers small, rose-color; styles 3–5. Fruit in drooping villose corymbs, on slender glabrous peduncles ¾ to 1½ in. in length, oblong, full and rounded at the ends, bright crimson, very lustrous, covered particularly toward the ends with scattered pale hairs, ¾ to 1 in. long, ½ to ¾ in. wide; calyx-cavity deep, comparatively narrow, the lobes elongated, glandular-serrate, villose on the upper surface, glandular-serrate above the middle, erect and incurved; flesh thick, yellow, dry and mealy; nutlets 3 to 5, prominently grooved and ridged on the back, ¼ to ⅓ in. long.

A tree sometimes 25 feet in height with a trunk a foot in diameter covered

with pale gray bark broken into small closely appressed scales and divided 6 or 7 feet above the ground into numerous ascending branches forming a broad symmetrical head, and slender, zigzag branchlets, dark green and coated when they first appear with matted pale hairs, during their first summer slightly villose, light chestnut-brown and marked by occasional small lenticels, chestnut-brown and very lustrous in their second year, and ultimately ashy-gray, and unarmed or armed with stout nearly straight chestnut-brown shining spines usually 1 to 1½ in. long.

Flowers about the middle of May. Fruit ripens and falls from the middle to the end of September.

Near Rochester, N. Y. Common. First distinguished in 1899 by *C. S. Sargent.*

It is a pleasure to associate this handsome and distinct thorn tree, which is one of the largest and most beautiful in the northern states, with the name of Mr. George Ellwanger, the distinguished horticulturist, in whose nurseries at Rochester a tree of this species, still standing, was large enough sixty years ago to be an object of interest and consideration.

Crataegus gemmosa, n. sp.—Leaves broadly oval or rarely broadly obovate, acute or acuminate, gradually narrowed and cuneate or occasionally rounded at the base, sharply and usually doubly serrate from below the middle, with straight glandular teeth, and often slightly lobed toward the apex, with short acute lobes; dark red and villose particularly below as they unfold, almost fully grown when the flowers open and then membranaceous, light yellow-green, nearly glabrous above, pale and villose below; at maturity thick and firm in texture, very dark dull green on the upper surface, pale and pubescent on the lower surface along the stout yellow midribs, deeply impressed and occasionally puberulous on the upper side and along the four or five pairs of slender primary veins running obliquely toward the apex of the leaf, 1½ to 2 in. long, 1 to 2 in. wide; on vigorous leading shoots more coarsely serrate, frequently divided into short lateral lobes, often 4 in. long and 3 in. wide, with rose-colored midribs and stout spreading primary veins; petioles stout, deeply grooved, more or less winged above, villose or pubescent, glandular while young, with minute bright red caducous glands, usually bright pink in the autumn, ¼ to ½ in. long; stipules linear, acuminate, bright red, glandular, caducous,

or on vigorous shoots lunate, acuminate, coarsely glandular-serrate, frequently ¼ in. long. Flowers ½ to ⅔ in. in diameter, in slender-branched villose open compound many-flowered corymbs; bracts and bractlets lanceolate to oblanceolate, acuminate, glandular-serrate, conspicuous; calyx-tube narrowly obconic, more or less villose, with matted pale hairs, or nearly glabrous, the lobes lanceolate, acuminate, coarsely glandular-serrate, with bright red glands, glabrous or villose on the outer surface, villose on the inner surface, reflexed after anthesis; stamens 20; anthers, small, rose-color; styles 2 or usually 3, surrounded at the base by a narrow ring of pale tomentum. Fruit on elongated slender pedicels, in drooping many-fruited glabrous or puberulous clusters, subglobose or short-oblong, scarlet, lustrous, ½ in. in diameter when fully ripe; calyx prominent, with an elongated narrow tube, and reflexed villose lobes, bright red toward the base on the upper side; flesh thick, clear yellow, sweet, very succulent; nutlets 2 or 3, ¼ in. long, broad, flat, prominently ridged on the back, with high rounded ridges, penetrated on each of the inner faces by a short broad deep cavity.

A tree occasionally 30 feet in height with a tall trunk 10 or 12 in. in diameter covered with dark brown scaly bark, stout spreading or ascending branches forming a rather broad open symmetrical head, or often shrubby and sometimes flowering when only a few feet high, and with stout glabrous zigzag branchlets marked by numerous oblong pale lenticels, dull orange-green when they first appear, light red-brown or yellow-brown and lustrous for two or three years and ultimately dull red-brown, and armed with straight or slightly curved thick bright chestnut-brown lustrous spines usually about 2 in. in length Winter buds globose, sometimes nearly ¼ in. in diameter, with broad ovate rounded lustrous bright red-brown outer scales pale and scarious on the margins.

Flowers in Ontario and central Michigan from the middle to the end of May. Fruit ripens the first of October.

Near Rochester, N. Y., *John Dunbar*, October, 1901; Humber river flats near Toronto, *D. W. Beadle*, May and September, 1901; London, Ont., *C. S. Sargent*, September, 1901; Belle Isle, Mich., *C. S. Sargent*, September, 1901; Grand Rapids, Mich., *Mrs. C. W. Fallass*, May, 1895, *Miss E. J. Cole*, May, 1896 and 1901, *Miss E. J. Cole*, and *C. S. Sargent*, September, 1901.

Well distinguished from the other species of the *tomentosa* group by its

remarkably large winter buds, by its stout thorns, dark usually broadly oval leaves, and by the size of the fruit, which, with the exception of that of *Crataegus tomentosa*, is smaller than the fruit of the other species of this group whose flowers have twenty stamens.

Crataegus blanda, n. sp.—Leaves oval to rhombic, acute or acuminate, occasionally slightly lobed toward the apex, broadly cuneate or concave cuneate at the entire base. coarsely crenulate-serrate above the middle, with glandular teeth; coated as they unfold with soft pale hairs; fully grown when the flowers open and then glabrous with the exception of large tufts of snow white tomentum in the axils of the primary veins, membranaceous, dark green and lustrous above, 1½ to 2 in. long and 1 to 1½ in. wide; at maturity subcoriaceous, yellow-green and lustrous above, pale below with slender midribs deeply impressed on the upper side and two or three pairs of slender primary veins extending very obliquely toward the apex of the leaf; on leading shoots often broadly ovate, full and rounded at the base, more deeply lobed above the middle, 2 to 2½ in. long, 1½ to 2 in. wide; petioles slender, slightly winged above, villose at first on the upper side, soon glabrous, ¾ to 1 in. long; stipules linear-lanceolate, entire, from ⅓ to ¼ in. long, caducous. Flowers 1 in. in diameter, on slender elongated pedicels, in broad loose many-flowered compound glabrous corymbs; bracts and bractlets linear, entire, caducous; calyx-tube broadly obconic, glabrous, the lobes gradually narrowed from broad bases, acuminate, entire or obscurely dentate, glabrous, reflexed after anthesis; stamens 20; anthers small, canary-yellow; styles 5. Fruit in many-fruited drooping clusters, subglobose to short-oblong, bright orange-red, marked by few pale lenticels, ¼ in. in diameter; calyx prominent, with a broad deep cavity and spreading lobes mostly deciduous before the ripening of the fruit; flesh thin, yellow, dry and mealy; nutlets 5, thin, pale brown, deeply grooved on the back, $\frac{3}{16}$ in. long.

A tree 25 or 30 feet in height with a tall trunk 10 or 12 in. in diameter covered with dark brown or nearly black fissured scaly bark, stout ascending branches forming a broad open irregular head, and nearly straight slender unarmed glabrous branchlets marked by large pale scattered lenticels, at

first dark orange-green, becoming dull red-brown during their first season and darker brown in their second year.

Flowers the first of May. Fruit ripens about the middle of October.

Dry hills near Fulton, Arkansas. Common. *B. F. Bush*, April 29, and October 15, 1901 (nos. 601, 1079).

This very distinct thorn belongs to a group of small-fruited still very imperfectly known species which is abundant with several forms in southern Arkansas, Louisiana, and Texas, and of which *Crataegus viridis* of Linnaeus is the type. From that species *Crataegus blanda* differs in the character and color of the bark, in the larger flowers and fruit, in the unarmed branches, and in its preference for dry uplands, *Crataegus viridis* with pale nearly white bark being found usually only on low moist bottom-lands along the borders of streams and swamps.

Crataegus Ravenelii, n. sp.— Leaves obovate, rounded and abruptly short-pointed or acute at the broad sometimes slightly lobed apex, gradually narrowed from above the middle to the cuneate elongated undulate glandular base, 3-nerved, coarsely and usually doubly glandular-serrate above, with large bright red ultimately dark persistent glands; nearly fully grown when the flowers open and then coated with long scattered matted pale hairs; at maturity thin but firm in texture, yellow-green, scabrate on the upper surface, pubescent on the lower surface along the slender nerves, 1 to 1½ in. long, about ¾ in. wide; on vigorous leading shoots often 2 in. long and 1½ in. wide, and divided above the middle into two or three pairs of broad lateral lobes; petioles slender, winged above by the decurrent bases of the leaf-blades, conspicuously glandular, tomentose at first, ultimately pubescent, from ¼ to ½ in. long; stipules linear to lunate, coarsely glandular-serrate, tomentose, caducous. Flowers about ¾ in. in diameter, in few or many-flowered simple tomentose corymbs; bracts and bractlets linear, glandular, caducous; calyx-tube narrowly obconic, thickly coated with long white hairs, the lobes lanceolate, villose on the outer surface, glabrous on the inner surface, glandular with small red glands, reflexed after anthesis; stamens 20, anthers small, pale yellow; styles 5, surrounded at the base by a broad ring of pale tomentum. Fruit in few-fruited puberulous spreading or drooping clusters, on short thick peduncles, globose or short-oblong, bright orange-red,

marked by occasional large dark lenticels, puberulous at the ends, $\frac{1}{3}$ to $\frac{1}{2}$ in. in diameter; calyx prominent, with a broad shallow cavity and enlarged spreading and appressed lobes; flesh thick, yellow, subacid; nutlets 5, ridged on the back with narrow elevated ridges, pale brown, $\frac{1}{4}$ in. long.

A tree 25 to 30 feet in height with a trunk 14 or 15 in. in diameter covered with thick dark brown bark deeply divided into narrow interrupted ridges broken on the surface into short thick plate-like scales, stout spreading and ascending branches forming a broad open irregular head, and thick slightly zigzag branchlets coated with hoary tomentum when they first appear, dark purple or reddish-brown and pubescent during their first summer, dark gray-brown and glabrous the following season, and armed with straight stout dull gray-brown spines usually about $1\frac{1}{2}$ in. long.

Flowers about the middle of April. Fruit ripens early in October.

Sandhills west of Augusta, Georgia, and Aiken, South Carolina.

Long confounded with *Crataegus flava* of Aiton, *Crataegus Ravenelii* differs from that species in the form of the leaves, the size of the flowers, the color of the anthers, and the size and character of the fruit. The oldest specimens which I have seen were collected near Aiken in 1880 by Henry William Ravenel, and the name of that distinguished South Carolina botanist may therefore fittingly be associated with this handsome thorn tree.

Crataegus lacera, n. sp.—Leaves rhombic to broadly ovate or rarely obovate, acute at the apex, broadly cuneate and entire at the base, divided above the middle into numerous narrow acuminate lobes, coarsely and often doubly serrate with straight glandular teeth; coated below as they unfold with thick hoary tomentum and villose above; nearly fully grown when the flowers open and then glabrous below and covered above with short scattered pale hairs; at maturity yellow-green, darker on the upper than on the lower surface, glabrous, thin but firm in texture, about $1\frac{1}{2}$ in. long and $1\frac{1}{4}$ in. wide, with slender yellow midribs and few remote primary veins only slightly impressed above; on vigorous leading shoots usually broadly ovate, often deeply three-lobed, very coarsely serrate, 3 to 4 in. long and broad; petioles slender, grooved, villose, ultimately glabrous or puberulous, narrowly wing-margined above, often red toward the base, $\frac{1}{4}$ to $\frac{1}{3}$ in. long; stipules linear, acuminate, villose, caducous; on vigorous shoots lunate, long-pointed, coarsely

glandular-serrate, villose, sometimes ¼ in. long. Flowers ¾ in. in diameter, in sparingly villose many-flowered compound corymbs; bracts and bractlets linear, caducous; calyx-tube narrowly obconic, glabrous, the lobes linear-lanceolate, elongated, coarsely glandular-serrate, glabrous on the outer surface, villose on the inner surface, reflexed after anthesis; stamens 20; anthers small, rose-color; styles 3 to 5. Fruit on short stout glabrous peduncles in erect few-fruited clusters, oblong, full and rounded at the ends, bright cherry red, lustrous, marked by occasional large dark lenticels, ½ in. long; calyx-cavity broad and shallow, the lobes small, nearly triangular, villose on the upper surface, mostly deciduous before the ripening of the fruit; flesh thick, orange-colored; nutlets 3 to 5, thin, broad, only slightly ridged on the rounded back, with low rounded ridges, light brown, $\frac{5}{16}$ in. long.

A slender tree 25 to 30 feet in height with a tall trunk occasionally 4 or 5 in. in diameter covered with pale gray-brown scaly bark, small spreading branches forming a narrow head, and slender slightly zigzag branchlets marked by small oblong scattered pale lenticels, dark olive green and villose when they first appear, light red-brown during their first summer and ultimately dull light gray, and armed with occasional slender straight bright chestnut-brown lustrous spines ¾ to 1¼ in. long.

Flowers about April 20th. Fruit ripens the middle of October.

Low rich woods near Fulton, Arkansas. Rare. *C. S. Sargent*, October 2, 1900, *W. M. Canby*, *B. F. Bush*, and *C. S. Sargent*, April 23, 1901, *B. F. Bush*, August and October, 1901.

This very distinct and handsome thorn somewhat resembles, in the structure of the flowers and in the form and lobing of many of the leaves, *Crataegus apiifolia*, from which, however, it differs in the usual form of the leaves and in the character of the fruit.

Crataegus Floridana, n. sp. (*Crataegus flava*, Sargent, *Silva N. Am.* 4:13. 1892, in part [not Aiton]).—Leaves obovate-cuneate, frequently 3-lobed at the apex, with short rounded lobes, gradually narrowed and cuneate at the entire base, finely serrate above, with straight or incurved glandular teeth, 3-nerved, with numerous thin secondary veins and reticulate veinlets; slightly villose above as they unfold, nearly fully grown when the flowers open and then light yellow-green, villose only

along the nerves and in their axils; in the autumn thick and firm, dark green and lustrous on the upper surface, pale on the lower surface, 1 to 1½ in. long and about ½ in. wide; petioles wing-margined above, glandular, tomentose, ultimately pubescent or glabrous, usually about ½ in. long; the leaves on leading shoots frequently 2 in. long and 1 in. wide, and sometimes divided by deep rounded sinuses into numerous lateral lobes. Flowers ⅝ in. in diameter, in few usually 3-flowered simple compact tomentose cymes: bracts and bractlets linear-lanceolate or oblanceolate, glandular, caducous; calyx-tube broadly obconic, coated with matted pale hairs, the lobes narrow, acuminate, glandular, villose toward the base on the outer surface and on the inner surface, reflexed after anthesis; stamens 20; anthers pale yellow; styles 4 or usually 5, surrounded at the base by a broad ring of shining white hairs. Fruit solitary or in 2- or 3-fruited drooping clusters, on short stout pubescent peduncles, obovate, bright orange-red, usually about ¾ in. long; calyx prominent with a broad elongated tube and reflexed glandular-serrate lobes; flesh thin, dry and mealy; nutlets 4 or 5, slightly ridged on the back, ⅓ in. long.

A tree, rarely more than 15 feet in height, with a tall straight trunk 6 or 8 in. in diameter covered with thick nearly black deeply furrowed bark broken into short thick plate-like scales, small drooping branches forming a handsome symmetrical head, and slender conspicuously zigzag pendulous branchlets coated when they first appear with long matted hairs, dark red-brown and more or less villose during their first season, dull dark brown the following summer, and armed with long slender straight spines, or unarmed.

Flowers the middle of March. Fruit ripens from the middle to the end of August.

Sand-barrens of northeastern Florida and probably northward along the coast of Georgia.

JAMAICA PLAIN, MASS.

A DESCRIPTIVE LIST OF THE PLANTS COLLECTED BY DR. F. E. BLAISDELL AT NOME CITY, ALASKA.

ALICE EASTWOOD.

(WITH TEN FIGURES)

THE plants forming the subject of this paper were collected at Nome city during the flowering season of 1900. This place has lately come into prominence on account of the valuable gold diggings located there, and is now visited annually by many people. On this account it seems well to publish a list of the plants found there, in order to give to others an idea of the flora, and also to assist botanists there who have at present no means of identifying the plants that bloom so profusely during the short summer. A mere list of names is of little value except to the worker in the herbarium, but a descriptive list, supplemented by a knowledge of orders and genera, or by some book in which these are given, will lead to the identification of almost all the species.

The Pteridophytes, Gramineae, Cyperaceae, Juncaceae, and Salicaceae have been determined by eminent authorities, and except in the last I have simply given the lists as they were given to me in each instance. It is with gratitude for this and other favors that I here acknowledge my obligations to my botanical friends.

The interesting description of the country which has been written by Dr. Blaisdell gives an excellent idea of the environment. Except in a few instances, where the environment has been especially noted, the plants were all collected in the tundra and within a radius of a few miles of Nome city.

THE VICINITY OF NOME CITY.[1]

Nome city is situated on the seacoast at the edge of the tundra. The latter extends inland, rising uniformly about two

[1] Written by Dr. F. E. Blaisdell.

hundred feet in four or five miles, where it becomes broken up and forms the rounded slopes of the hills and small mountains, which in the vicinity of Anvil mountain do not reach an altitude of more than 400 to 1000 feet. In this particular region the easterly slopes of this mountain and adjoining hills form the divide between the tributaries of the Nome river, that flow in an easterly direction, and those of the Snake river, that flow south-

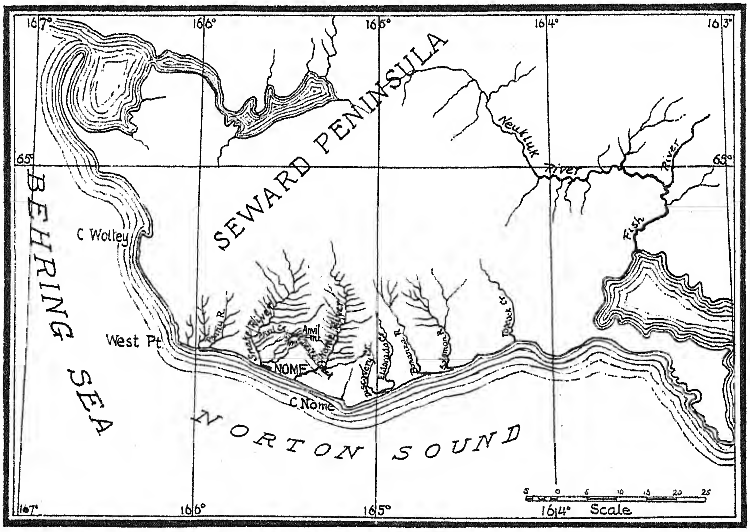


FIG. 1.—MAP, showing region where a botanical collection was made by F. E. Blaisdell, M.D.

westerly. Dexter creek is one of the large creeks of this vicinity that empty into the Nome river, and has its origin in the easterly slopes of Anvil mountain and the neighboring hills, six miles north of Nome city, and courses two and a half miles eastward to the Nome river. The highest peak in this region is King mountain (so called in the neighborhood), situated between Dexter creek on the southeast and Anvil creek on the west; also between Anvil mountain on the south and Nome river on the east.

The tundra is truly a marshy plain from its commencement at the seashore to the highest mountain, although the latter by

its altitude is more quickly drained, and becomes comparatively dry earlier in the season. It is roughened by hummocks of moss and bunch grass varying from a few inches to two feet high, and in circumference from that of a stove-pipe in the marshiest places to the broad, flattened, and rounded knolls of the general surface. In the crevices between the hummocks, which may be narrow and deep or shallow and varying in breadth, little streams of various sizes trickle along, working their way to the larger creeks. Here and there are perennial springs. Most of the water that flows from the tundra comes from the thawing of the subterranean ice, and the small glaciers that remain in the higher valleys after the snow disappears. These endure the entire season unless the summer is unusually warm. As the season advances and the ice and snow gradually disappear, the smaller streamlets dry up, so that in the month of August the land is comparatively dry. More or less rain falls during the summer. Some seasons are very rainy, as the summer of 1899, while that of 1900 was dry. Near the end of the month of July, I found ice six inches beneath the surface of the ground. This formed the floor of a ground squirrel's burrow which I explored.

Everywhere the ground is covered with mosses, lichens, and prostrate plants, the mat varying in thickness from one to several inches. Within the small crevices between the hummocks grow many of the small plants. The willows are the largest shrubs of the region, on the tundra being from two to three feet high, but along the rivers attaining a height of eight or more feet. They are scattered here and there, or form thickets an acre or less in extent. Many species of plants find a home in the shelter of these thickets.

I could make out but two or three life-zones in this region. That over which I collected may be bounded as follows: on the south by the seacoast at Nome city; on the west by Snake river and its tributary, Glacier creek; on the east by Nome river; on the north by Boston and Grouse creeks, tributaries of Glacier creek and Nome river. In the lower zone the several species of plants have a general distribution, an aggregation of individuals

of a species occurring here and there where the conditions are more favorable to their growth. In the upper zone, above four hundred feet altitude as an approximate lower limit, a number of species occur that were not to be found on the lower levels. The general conditions are about the same in both zones. Altitude and dryness from the earlier drying up of the excess of water, and rocky ledges attracting the sun's rays, are the main differences in environment observed in the upper zone.

When I landed, June 18, the anemones and primroses were blooming, and many willows were unfolding their catkins. All species had almost finished blooming by the end of August, when the first frosts terminated plant activity, and by the middle of September everything was frozen up.

The following list includes all the species I saw except one species of Allium, one of Veratrum, one of Aquilegia, and one of Delphinium. There were also some mosses and lichens that have not yet been determined.

FILICES.[2]

1. Dryopteris fragrans (L.) Schott.
2. Filix fragilis (L.) Underw.
3. Filix montana (Lam.) Underw.
4. Gymnopteris triangularis (Kaulf.) Underw.
5. Phegopteris phegopteris (L.) Underw.

EQUISETACEAE.[2]

6. Equisetum pratense Ehrh.
7. Equisetum variegatum Schleich.

LYCOPODIACEAE.[2]

8. Lycopodium alpinum L.
9. Lycopodium annotinum L. The so-called var. pungens.
10. Lycopodium Selago L.

[2] Determined by L. M. Underwood.

GRAMINEAE.[3]

11. Alopecurus alpinus J. E. Smith.
12. Arctogrostis latifolia Griseb.
13. Bromus pacificus Shear. A very much reduced form, possibly already published under some older and as yet unidentified name.
14. Elymus mollis Trin.
15. Poa alpina L.
16. Poa arctica R. Br.
17. Savastana alpina (Sw.) Scribn.

CYPERACEAE.[4]

18. Carex capitata L.
19. Carex compacta R. Br.
20. Carex lagopina Wahl.
21. Carex macrochaeta C. A. Meyer.
22. Carex misandra R. Br.
23. Carex rigida Good.
24. Carex scirpoides Mx.
25. Eriophorum angustifolium Roth.
26. Eriophorum vaginatum L.

JUNCACEAE.[5]

27. Juncoides campestre sudeticum (Willd.) Coville.
28. Juncoides parviflorum (Ehrh.) Coville.
29. Juncoides sp.
30. Juncus castaneus Smith.
31. Juncus Haenkei E. Mey.

LILIACEAE.

32. Lloydia serotina Sweet Hort. Brit. ed. II. 527.—*Anthericum serotinum* L. Sp. pl. ed. 2. 444. 1762; *L. alpina* Salisb. Trans. Hort. Soc. **1**: 328. 1812.—The small bulb or corm is concealed by the scarious bases of former leaves which also

[3] Determined by F. Lamson-Scribner.

[4] Determined by Theodor Holm. [5] Determined by F. V. Coville.

sheath the lower part of the present leaves and the flowering stem: leaves filiform, 9–12^{cm} long, longer or shorter than the stem; cauline leaves generally 3, clasping at base and dilated, involute: flowers solitary, erect, terminating the stem: perianth with the divisions 3-nerved, oblanceolate, obtuse, incurved at base: stamens half as long as the perianth (5^{mm}), with flattened subulate filaments and elliptical basifixed anthers: capsule when ripe shorter than the marcescent perianth, angled; the valves obcordate at apex, cuneate at base, cuneate-obovate in general outline. The flowers are like small erect lilies, dull white, veined with green or purplish lines.

Type range: "in alpibus Angliae, Helvetiae, Taureri rastadiensis, Wallaesiae."

33. Tofieldia palustris Huds. Fl. Angl. ed. II. **1**: 175. 1778.— *T. borealis* Wahl. Fl. Lapp. 89. 1812.— Roots fibrous: leaves tufted at base, erect, equitant, linear-acuminate, about 2^{cm} long, 1^{mm} wide, with three prominent nerves: scape naked or with one leaf near the base, 8–15^{cm} high: raceme short, less than 3^{cm} long, densely flowered; pedicels short, 1–2^{mm}, with three very short papery bracts at base: perianth marcescent, shorter than the ripe capsule, which is elliptical-orbicular, tipped by the short stout divergent styles with capitate stigmas: seeds many, ellipsoidal, appendaged by the funiculus.

34. Zygadenus elegans Pursh. Fl. Am. Sept. **1**: 241. 1813.— *Z. glaucus* Nutt. Journ. Acad. Philad. **7**: 56. 1834.—Stem about 3^{dm} high from a coated bulb, glaucous and glabrous: leaves mostly basal, grass-like, usually one or two on the stem: flowers racemose, distant on the lower part of the stem, closer near the summit; bracts exceeding the pedicels, 1–2^{cm} long, scarious: flower 15–20^{mm} in diameter: segments of the perianth whitish, veined with green; inner ones with well-marked claw; outer ones broader, narrowed to the base; gland yellow above the claw, deeply emarginate: filaments shorter than the perianth.

Type locality: "on the waters of Cokahlaishkit river, near the Rocky mountains.— M. Lewis."

IRIDACEAE.

35. **Iris arctica,** n. sp.—Rhizome stout, oblique, clothed with brown sheaths which are split into fibers: leaves erect, thin, lax, 2–2.5^{dm} long, 5–8^{mm} broad, acuminate, veiny; young leaves rosy at base: stem almost twice as long as the leaves, simple, with one or two leaves, the top leaf rarely reaching the spathe: spathes one-flowered; outer bract leaf-like, acuminate, 3–6^{cm} long, shorter than or surpassing the pedicels; the two inner thinner, acute: pedicels scarcely exserted beyond the spathes in flower, 3–5^{cm} long in fruit: tube of the perianth cylindraceous, 5^{mm} long, 2^{mm} in diameter; falls widely spreading, with claw 2.3^{cm} long, 1^{cm} broad at top, narrowed at base, blade ovate orbicular, violet with a greenish-yellow spot where it joins the claw, 3.5^{cm} long, almost 4^{cm} broad, veiny; standards inconspicuous, variously shaped, generally ovate with a sort of lobe at top surmounted with a long setaceous appendage, the much broader lower part, corresponding to the claw, white blotched with purple on the lower half: style branches 3^{cm} long; crests generally entire and straight on the inner side, laciniate-dentate on the outer, oblong in general outline, veiny; stigma deltoid: stamens with filaments as broad as the anthers and a little longer, the latter 1^{cm} long: ovary 3-sided, narrowed at the two ends: immature capsule ellipsoidal.

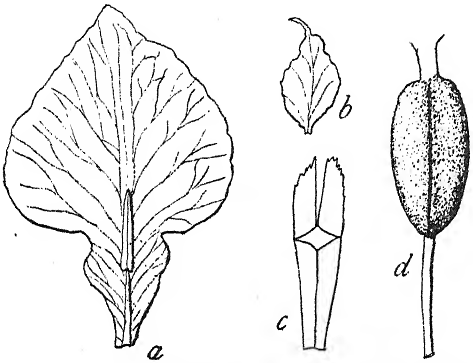


FIG. 2.—IRIS ARCTICA, n. sp. *a*, blade; *b*, standard; *c*, style branch; *d*, ovary. All three-fourths nat. size.

This is nearest to *Iris setosa* Pallas, from which it differs in having simple stems and one-flowered spathes, and especially in the shape of the divisions of the flower. It resembles this and other allied species in having the standards inconspicuous and very much smaller than the falls. The description of *Iris setosa* has been taken from Baker's *Irideae*, p. 11, also from Ledeb. *Fl. Ross.* 4 : 96, the original reference.

SALICACEAE.[6]

36. SALIX ALAXENSIS Coville, Proc. Wash. Acad. Sci. **2** : 280 1900; *idem* 3 : 311. *pl. 34*. 1901.—*S. speciosa* Hook. & Arn Bot. Beech. 130. 1832; *S. speciosa alaxensis* Anders. DC. Prod. **16²** : 275. 1868.—Stems rather stout, densely white-tomentose or flavescent: leaves obovate to oblong-lanceolate, acute or acuminate, densely tomentose on the lower surface, glabrous or with some woolly hairs on the upper; the largest leaves 5.5^{cm} long, $2–5^{cm}$ wide; petioles 5^{mm} long, shorter than the linear-lanceolate stipules; these $5–10^{mm}$ long, white-woolly: female catkins 6^{cm} long, the bracts black, clothed with long white woolly hairs: style long; stigma with linear two-parted lobes: capsules ovate-acuminate, sessile, clothed with silky hairs.

Type locality: "Alaxa Americae occidentali-borealis." On the banks of Nome river.

37. SALIX CHAMISSONIS Anders. DC. Prod. **16²** : 290. 1868.—Stems shining, chestnut-brown: leaves (in bud) glandular-serrate, green on the upper surface, glaucescent and somewhat lanate on the lower; petioles short, about as long as the gland-toothed stipules: catkins with leafy peduncles, densely flowered, $3–5^{cm}$ long; scales black, clothed with long white silky hairs that almost equal the capillary filaments but are shorter than the styles: capsules clothed with sparse short white pubescence, tapering at apex to the long black style; divisions of the stigma short with the lobes as long.

Type locality: "in sinu *S. Laurentii*."

38. SALIX GLAUCA L. Sp. Pl. 1019. 1753.—Old stems chestnut-brown, young ones white-tomentose: leaves elliptical, subovate, acute, tapering to a short petiole which is 5^{mm} long, generally surpassed by the white-woolly stipules, upper surface green, lower glaucous, clothed with fine silky hairs which are more abundant on the lower surface than the upper; longest leaf 4^{cm} long, 12^{mm} broad: catkins small, subtended by the leaves, 1.5^{cm} long; scales arranged in whorls 1^{mm} apart, orbicular,

[6] Determined by F. V. Coville.

brown or black, white hairy: stamens 2 from each scale, with filaments 5^{mm} long.

Type locality: "in Alpibus Lapponicis and Pyrenaicis."

39. SALIX PHLEBOPHYLLA Anders. Oefv. Kongl. Vet. Akad. Foerh. **15**:131. 1858.—About 2^{cm} high, from branched woody prostrate stems: leaves crowded on short petioles, ovate-orbicular, glossy, veiny, green on both sides but with some long loose woolly hairs on the lower surface, 1^{cm} long, 7^{mm} wide, with obtuse apex and revolute margin; old leaves persisting and becoming skeletonized: catkins (female only) about 1^{cm} long, surrounded by leaves at base; scales black, orbicular, clothed with long white wool: styles purplish, about equaling the woolly hairs of the scales; stigma with each division two-lobed.

40. SALIX PULCHRA Cham. Linnaea **6**:543. 1831.—Stems dark brown, glossy: leaves (immature) glabrous or slightly villous, sparingly glandular-serrate; stipules linear-lanceolate, green on the upper surface, glaucescent on the lower: peduncles short, not leafy, but with one or two black scales at base: catkins oblong-elliptical, 2^{cm} long; scales black-lanate but not densely so; female catkin with long yellow styles and stigmas twice-lobed: capsules ovate-acuminate, slightly hispid.

Type locality: "in Promontorio Espenbergii Americae transbeeringiensis, inque insula Sti. Laurentii."

41. SALIX RETICULATA L. Sp. Pl. 1018. 1753.—Stems 5–10^{cm} high, brown, prostrate, woody: leaves elliptical, ovate or orbicular, generally obtuse, green and glabrous on the upper surface, glaucous and villous on the lower, beautifully reticulate-veiny on both sides, 1–3.5^{cm} long, 1–2.5^{cm} wide, petioles half to two-thirds as long as the blade, reddish: peduncles longer than or equaling the catkins, which are slender, 1.5–3^{cm} long: male catkins with bracts subverticillate, reddish, pubescent and densely ciliate with short white hairs; filaments two to each bract, 2^{mm} long: female catkins more closely flowered, and the bracts almost glabrous: capsules sessile, tomentose, ovate-acuminate, 4^{mm} long; styles less than 1^{mm} long; stigma with the two short divisions each two-cleft.

Type range: "in Alpibus Lapponiae, Helvetiae." Collected on Mt. King.

42. SALIX sp.—Stems glabrous or slightly pubescent: leaves elliptical, acute or obtuse at apex, bright green on the upper side, glaucous on the lower, with margin entire or sparingly glandular-toothed; largest leaf 6.5^{cm} long, 3^{cm} broad; petioles 1–3^{mm} long; stipules only on the younger leaves, ovate, glandular-toothed, about as long as the petioles: catkins 2^{cm} long, loosely flowered, on short leafy peduncles; bracts oblong, brown with silky wool at apex: capsules on short pedicels, ovate-lanceolate, acuminate, 4^{mm} long; styles short; stigmas capitate at first, later two-lobed.

This is an undetermined species which Mr. Colville writes has been collected also at other places.

BETULACEAE.

43. BETULA NANA L. Sp. Pl. ed. 2. 1394. 1763; Fl. Lapp. 274. *pl. 6. fig. 4.*—Low shrub with brown bark, white dotted: leaves small, orbicular, 5–10^{mm} wide, irregularly dentate, with petioles 2^{mm} long.

Type range: "in Alpibus Lapponicis, paludibus Sueciae, Russiae."

The specimen is without flowers or fruit. The catkins are described as small.

POLYGONACEAE.

44. OXYRIA DIGYNA Hill Hort. Kew. 158. 1765 (ex Index Kewensis).—Stems erect, 2–2.5^{dm} high, with branched inflorescence: radical leaves orbicular-reniform, glabrous, on long petioles: flowers on slender pedicels, several from each scaly bract, drooping; sepals four, two appressed to the fruit, the other two-spreading, carinate on the back: fruit orbicular, red-winged: stigmas two, tufted at the deeply emarginate apex.

45. POLYGONUM BISTORTOIDES Pursh. Fl. Am. Sept. 271 1814.—Stems erect, 2^{dm} high, from thick rootstocks: radical leaves oblong, 3–5^{cm} long, smooth and deep green on the upper surface, pale green on the lower, margin crisped-undulate and disposed to be revolute; sheaths not jointed to the petiole, oblique at top, surpassing the petiole of the cauline leaves: flowers white, turning pink, on slender pedicels, in a dense racemose spike, 3^{cm} long, 2^{cm} wide: stamens with white filaments and violet

anthers, exserted together with the style, twice as long as the perianth: bracts brown, scarious.

Type locality: "in low grounds on the banks of the Missouri, called Quamash-flats. M. Lewis." Too young for fruit.

46. POLYGONUM VIVIPARUM L Sp. Pl. 360. 1753.—Stems erect from a bulb-like rootstock: radical leaves oblong to lanceolate, or sometimes ovate-cordate, dark green and glabrous above, glaucous and sparsely pubescent below, tapering at both ends, $3–4^{cm}$ long, $3–6^{mm}$ wide; petioles about as long as the blades; stem leaves strongly revolute, with the brown sheaths longer than the petioles: spicate raceme linear-oblong, $4–5^{cm}$ long, including the bulb-bearing lower half: stamens almost twice as long as the perianth, with filaments longer than the styles, and anthers dark purple.

Type range: "in Europae subalpinis pascuis duris."

47. RUMEX ACETOSA L. Sp. Pl. 337. 1753.—Dioecious: stem erect, ribbed, $4–5^{dm}$ high, glabrous throughout: leaves few, ovate, auriculate or sagittate at base, acute or obtuse at apex, $2–3^{cm}$ long; sheaths about as long as the broad petioles on the cauline leaves, much shorter on the radical: flowers panicled; pedicels jointed in the middle; perianth divisions reflexed; fruiting bracts ovate, veiny, reddish, without grains on the back, but with a scale at base: seeds wing-angled.

Type range: "in Europae pascuis."

48. RUMEX sp.—Stems $2–3^{dm}$ high, rather stout, glabrous, red or green, striate, from a thick root: radical leaves narrowly oblong on broad petioles, usually cordate at base, obtuse at apex: cauline leaves one or two, with sheaths as long as the petioles, often with crisped margins: panicle thyrsiform or virgate; flowers drooping on slender pedicels, hermaphrodite: stamens exserted: valves of the immature fruit oblong, without grains or scales.

Too immature for determination, but it seems to be near *R. occidentalis nanus* Trelease, Rep. Mo. Bot. Gard. **3**: 82. 1892.

PORTULACACEAE.

49. CLAYTONIA TUBEROSA Pall. ex Willd. in Roem. & Schult. Syst. **5**: 436. 1819.—Stems slender with two lanceolate leaves, opposite or alternate, 1–2^{cm} below the inflorescence: these leaves about 2^{cm} long, narrowed at base, sessile, obtuse at apex, glabrous: flowers umbellately panicled, with pedicels recurved in fruit, 1–2^{cm} long; bracts red, sheathing or wanting on all except the lowest: calyx of two broad, ovate, accrescent sepals: petals white, 1^{cm} long, more than twice as long as the sepals, 6^{cm} broad, truncate or slightly emarginate at apex: filaments dilated at base, half as long as the petals; anthers pink, narrowly oblong: seeds not ripe.

The specimens at hand are without radical leaves or roots, but seem to agree with this species as described in Gray's *Syn. Fl.* **1**: 272.

50. MONTIA SARMENTOSA Robinson, Syn. Fl. N. Am. **1**: *272.* 1897.—*Claytonia sarmentosa* C. A. Meyer, Mém. Soc. Nat. Mosc. **7**: 137. *pl. 3.* 1829.—Stems glabrous, from slender running roots, producing runners: radical leaves on long margined petioles, obovate or ovate; cauline leaves ovate, sessile, clasping: flowers racemose with recurved pedicels, without bracts: sepals broadly ovate, slightly surpassed by the capsule: petals pink or white, 1^{cm} long, 5^{mm} wide, thrice as long as the sepals, with a distinct claw and obcordate blade: seeds two or three, shining, black, granulate mucronulate.

CARYOPHYLLACEAE.

51. ARENARIA ARCTICA Stev. DC. Prod. **1**: 404. 1824; Cham. & Schl. Linnaea **1**: 54. 1826; Hook. Fl. Bor.-Am. *pl. 34 B.*—Stems tufted-cespitose, glandular: lowest leaves closely imbricated in bunches, glabrous, linear, obtuse, apparently fleshy, somewhat falcate, 5^{mm} long, the margin without cilia: stems 2–3^{cm} high, with a pair of ovate obtuse membranously-margined slightly ciliate connate-clasping leaves about 1^{cm} distant from the flower: calyx green or purplish, with the divisions ovate, 4^{mm} long, obscurely nerved, the margins membranous, purplish or white, the apex somewhat incurved but not cucullate: petals

broadly obovate, a little more than 7^{mm} long, 5^{mm} broad, tapering to a short yellow claw: filaments flat, slightly surpassing the sepals, abruptly dilated at the very base and thickened: ovary ovoid, obtuse, $2–5^{mm}$ long, a little longer than the styles.

Type range: "in littore Sibirico maris glacialis."

52. ARENARIA LATERIFLORA L. Sp. Pl. 423. 1753.—Stems slender, weak, 4^{cm} high: leaves elliptic-oblong to oval, $5–10^{mm}$ long, finely ciliate on the margin, papillose-roughened on the surface: flowers on slender peduncles, surpassing the leaves: sepals suborbicular, 1^{mm} long, one-nerved, with white membranous margins: petals white, twice as long as the sepals: capsule globular.

Type range: "in Siberia." Only one specimen obtained, and it was one-flowered.

53. ARENARIA MACROCARPA Pursh. Fl. Am. Sept. **1**: 318. 1813; Cham. & Schl. Linnaea **1**: 54. 1826; Hook. Fl. Bor.-Am. *pl. 34 A*.—Stems matted-cespitose, densely clothed with imbricated leaves, all except the terminal tuft dry and bleached: leaves linear, obtuse, denticulate, falcate, 6^{mm} long: flowering stems $2–3^{cm}$ high, glandular, slender, with one or two pairs of leaves, one-flowered with the peduncle half as long as the stem: stem-leaves shorter and broader than the basal leaves, connate-clasping, glandular: sepals obscurely 3-nerved, linear, 7^{mm} long, membranously purple- or white-margined, incurved at apex but scarcely cucullate: petals white, oval-obovate, more than 3^{cm} long, 5^{mm} broad: stamens with flat filaments widening gradually to the base where they become fleshy and suddenly dilated, surpassing the sepals: ovary ovoid, obtuse, 6^{mm} long, scabrous along the edges of the valves.

Type range: "on the northwest coast of America.—Nelson." The ripe capsule is not present on any of the specimens.

54. ARENARIA PHYSODES Fisch. DC. Prod. **1**: 413. 1824.—*Merckia physodes* Fisch. Linnaea **1**: 59. 1826.—Stems branching from weak decumbent basal stems, rooting at the joints and somewhat clothed with persistent dead leaves, growing to a height of about 5^{cm}, glandular-hirsute and ribbed: leaves broadly

ovate to suborbicular, 5–10^{mm} long, cuspidate; petioles very short and broad, a little shorter than the internodes, margins ciliate: flowers at first solitary, later with a second flower from the axil of the top pair of leaves; peduncles 1^{cm} long, glandular like the stem: sepals ovate to oval, acute or obtuse, 5^{mm} long, 3^{mm} wide, the margin purple, sparingly glandular-hairy: petals with short yellow claws and broad white ovate-orbicular blades, together a little longer than the sepals: capsule depressed-globose, inflated, surpassing the calyx and corolla when ripe, 6–7^{mm} in diameter: styles three, persistent.

Type locality: "in Kamschatka."

55. ARENARIA ROSSII Richardson. R. Br. in Parry 1st Voy. App. 272. 1823.—Matted cespitose: lowest leaves imbricated, the upper pairs more distant, glabrous, linear, three-sided, somewhat fleshy, 4^{mm} long: peduncles capillary, erect-spreading or slightly curved at tip, 2–4^{mm} long: sepals ovate, acute, about 2^{mm} long, gibbous, with the apex involute, membranously margined with white or purple: petals linear to oblanceolate, 2.5^{mm} long, truncate or obtuse at apex: stamens 10, with the alternate filaments about equaling the sepals: filaments from a yellow, fleshy, shield-shaped, five-lobed disk at base of ovary: anthers orbicular, retuse at each end: capsule sessile, conical, five-angled, purplish, tipped by the three styles.

Type locality: "Melville island." In *Index Kewensis* this is made a synonym of *A. stricta* Michx.

56. CERASTIUM ALPINUM FISCHERIANUM Torr. & Gray Fl. 1:188. 1838.—*C. Fischerianum* Seringe, DC. Prod. 1:419. 1824. —Stems 1.5–2^{dm} high, villous pubescent below, glandular above: leaves lanceolate-acuminate, 10–15^{mm} long, 2–4^{mm} wide: flowers cymosely panicled: peduncles 1–2^{cm} long: petals twice as long as the sepals, 1^{cm}: pod exserted from the calyx 5–6^{mm}.

Type locality: "in Kamschatka."

57. CERASTIUM VULGATUM L. Spec. Pl. ed. 2. 627. 1762.—Lower part of stem pilose, upper viscid-pubescent: leaves in pairs, distant, oblong, 10–15^{mm} long, pilose: flowers capitate-cymose, the upper pair of leaves subtending the inflorescence

like an involucre; oldest flower with the pedicel curving downwards, longer than the calyx: sepals nerved, pilose, white-margined, lanceolate, 6^{mm} long, apex obtuse or emarginate: petals white, as long as the sepals: capsule a little longer than the calyx, the valves revolute after opening.

Type range: "in Scaniae aut Europae australioris pratis."

58. LYCHNIS APETALA L. Sp. Pl. 437. 1753.—Stems 12–15^{cm} high, glandular-villous: radical leaves obovate to lanceolate, 15^{mm} long; cauline leaves two pairs: flowers pendulous at first, later erect: calyx inflated, glandular, having ten purplish nerves: petals exserted about 2^{mm}.

This is perhaps var. *elatior* Regel. Bull. Soc. Nat. Mosc. 34: 573, of which the type locality is given as Kodiak island and northward in Alaska to Kotzebue sound (ex Gray's *Syn. Fl. N. Am.* 1: 226).

59. SILENE ACAULIS L. Sp. Pl. ed. 2. 603. 1762.—Cespitose, often covering broad areas: leaves linear, one-nerved, glabrous, ciliate on the margins, 5^{mm} long: flowers on peduncles about their own length: calyx purplish with deltoid divisions, ciliate on the margins: petals rose-color, with spreading blades and exserted claws: stamens exserted.

Type range: "in Alpibus Lapponicis, Austriacis, Helveticis, Pyrenaecis." This is commonly regarded as a flowering moss as it covers the ground like moss.

60. STELLARIA LONGIPES Goldie, Edinb. Phil. Jour. 6: 327. 1822.—Stems erect, with erect branches, glaucous or often shining, glabrous: leaves lanceolate-acuminate to ovate, one-nerved, about 5–10^{mm} long, with longer internodes: flowers cymose, the lateral ones with a pair of membranous bracts below the middle; peduncles long, almost 3^{cm}: sepals ovate, keeled, 2^{mm} long, with the margins white-membranous, ciliate: petals white, surpassing the sepals: capsule glossy, surpassing the calyx by about 1^{mm}, brownish (perhaps not ripe).

Type locality: "woods near Lake Ontario."

RANUNCULACEAE.

61. ACONITUM DELPHINIFOLIUM DC. Syst. 1: 380; Reichenb. Monogr. Gen. Aconiti 79. *pl.* 9.—Stems erect, 4–5^{dm} high,

slender with few leaves, simple or with few erect branches, retrorsely pubescent: leaves about 5^{cm} across, 3–5-parted or divided with the divisions laciniately cleft into linear acute lobes, $2–3^{mm}$ broad, glabrous, paler on the lower surface; petioles long and slender, glabrous, slightly dilated only at the base: flowers few on long pedicels, lowest pedicel 5^{cm} long from a leaf-like bract; the upper bracts with one or two divisions; bracts and pedicels pubescent: hood not much surpassing the other sepals; lower sepals half as broad as the lateral and of the same length: follicles erect, spreading at apex, marked with dark reticulation, sparsely pubescent.

Type locality of Reichenbach: "in Kamtschatka" (ex Ledeb. *Fl. Ross.* 1:70). Depauperate one-flowered specimens are not uncommon. Common everywhere, especially under the willow trees.

62. ANEMONE NARCISSIFLORA **uniflora** Eastwood, n. var.—Stems $1–2^{dm}$ high, glabrous or villous: radical leaves pedately 3-divided with the cuneate-flabelliform divisions cleft into 5–7 unequal, oblong or linear, acute lobes; petioles dilated at base, imbricated, two- to three-nerved, $4–6^{cm}$ long; blade $2-4^{cm}$ across, generally villous-ciliate on the margin, paler on the lower side than the upper; involucral leaves similar to the divisions, sessile, more or less densely villous at base and on the lower surface, 1.5^{cm} long: flowers solitary in the involucre on a peduncle elongating from $3–5^{cm}$: sepals rhombic-obovate, 1.5^{cm} long, almost 3^{cm} broad, though somewhat unequal: stamens numerous: akenes in a globular head, glabrous, with the style much recurved.

This differs so much from the usual form in general appearance as well as in the number of flowers that it seems deserving of varietal rank.

63. ANEMONE PARVIFLORA Michx. Fl. 1:320. 1803.—Stems erect from a creeping rootstock, woolly pubescent, 5^{cm} to 2.5^{dm} high: leaves palmately 3-divided, with the divisions broadly cuneate, three-lobed with uneven rounded lobes, bright green on the upper surface, paler on the lower, the marginal teeth callous-tipped, reniform in general outline, $1–3^{cm}$ across; petioles long and slender, sheathing at base, striate; involucral leaves

more deeply lobed, sessile or on very short broad petioles: flowers terminal, solitary, white or tinged with blue, almost 3^{cm} in diameter: sepals obovate, about 3^{cm} broad: akenes in an oval head, densely white-woolly, with the capillary styles generally deciduous.

Type locality: "ad amnes in sinum Hudsonis defluentes."

64. ANEMONE RICHARDSONI Hook. Fl. Bor.-Am. 1:6. *pl. 4.* 1840.—Stems erect, from slender creeping rootstocks, $1–1.5^{dm}$ high: radical leaves three- to five-lobed, the lobes broadly cuneate, irregularly dentate, reniform in outline; petioles $2–4^{cm}$ long, villous, sheathing only at the very base, veined; cauline leaves three, involucrate, sessile, similar to the radical leaves but not so broad: peduncles lengthening from $2–12^{cm}$: sepals yellow, ovate, veiny, pilose on the lower side, obtuse: akenes in a short head, pointed with the long slender uncinate styles which are about 5^{mm} long.

Type range: "Eastern primitive district, shores of Hudson's bay: barren ground, Rocky mountains, from lat. 55° to 68°, in wet mossy ground. Unalashka and throughout all Siberia."

65. COPTIS TRIFOLIA Salisb. Trans. Linn. Soc. 8:305.—*Helleborus trifolius* L. Sp. Pl. 558. 1753.—Rootstock yellow, slender, filiform: leaves all radical, trifoliate; divisions obovate-cuneate, with crenate-dentate margins and mucronate teeth, evergreen, glossy, glabrous: petioles long, slender, almost equaling the scape: scape 1-flowered (in the only specimen): sepals oval, white, tinged with purple, 6^{mm} long: petals orange, clavate, 2^{mm} long: stamens surpassing the petals: fruit wanting.

Type range: "in Canada, Siberia."

66. **Delphinium Blaisdellii** Eastwood, n. sp.—Root unknown: caudex woody, branching: lowest leaves less dissected than the upper ones, with four or five 3–5-parted divisions, obovate in outline, laciniately cleft into linear lobes which are entire or with a few teeth near the apex; divisions of the upper leaves with 4–7 linear-acuminate divisions diverging pinnately from the broad rhachis and diminishing towards the apex; petioles dilated at base (1^{mm} broad), somewhat canescent with silky pubescence, longer

than or equaling the blades: lowest flowers axillary on downy peduncles, which are erect but recurve at apex, about 2^{mm} long; upper ones from slender bracts, forming a rather dense raceme: divisions of the calyx about as long as the spur, elliptical, silky villous exteriorly, dark blue with black spot near the apex; spur slender, 2.5^{cm} long, tapering to an obtuse apex less than 1^{mm} wide, straight or curved, slightly erect or horizontal: upper petals white, veined with blue; lower bearded with yellow hairs: immature capsules densely clothed with white silky wool.

This may have been identified with *D. Menziesii* Lindl. Bot. Reg. *pl. 1192*, as this seems to have been the only species reported from the arctic region. It is very different from the figure in the *Botanical Register*, and quite unlike any specimen identified as that species in the herbarium of the California Academy of Sciences. Without the root and ripe or fully grown fruit, it is not wise to name species of Delphinium, but in a list like the present one it is better to name it, if it is described, than to leave it described but unnamed.

67. RANUNCULUS NIVALIS L., Sp. Pl. 553. 1753; Fl. Lapp. *pl. 3. fig. 2.*—Roots fibrous: caudex often branched, sheathed with membranous bases of old leaves: radical leaves cuneate, 3–5-lobed, on long petioles; cauline sessile, one or two with deeper and more spreading divisions: flowers yellow, 2^{cm} across: calyx of orbicular sepals clothed with brown hairs: petals almost twice as long, orbicular to obovate, obtuse, veiny: head of akenes oblong, on an elongated peduncle; akenes orbicular, somewhat turgid, tipped by a straight or curved style, glabrous or slightly villous.

Type range: "in Alpibus Laponiae, Helvetiae."

68. RANUNCULUS PYGMAEUS Wahl. Fl. Lapp. 157. *pl. 3. fig. 3.* 1812.—Stems woolly-pubescent, low and slender ($3–8^{cm}$ high), from an ascending rootstock: radical leaves pedately 3–5-cleft, with unequal rounded lobes: petioles unequal, much dilated at base, 3-veined, sparsely ciliate: cauline leaf about the middle of the 1-flowered stem, palmately 3-cleft: flowers yellow, $8–9^{mm}$ across: sepals villous, about as long as the orbicular petals: akenes in an oblong head, tipped with a curved style.

Type locality: "alp. Lapponiae" (ex Ledeb. *Fl. Ross.* 1: 36). On the edge of glaciers, Swan gulch.

69. **Ranunculus verticillatus** Eastwood, n. sp.—Stems slender, weak, reclining or ascending, glabrous near the base, sparsely and finely pilose above, simple or dichotomously branched: radical leaves none; cauline leaves divided palmately to the base, the linear entire divisions appearing like 4–6-whorled leaves, varying but little in length, in different leaves from 5–20^{mm} long to 3^{mm} wide, minutely appressed-ciliate on the margins, and with longer cilia at the base, dotted on the upper surface (under a lens) with the minute pustules of the pubescence: earliest peduncle (if more than one) naked, 3–10^{cm} long; later ones, with one or rarely two leaves, having fewer divisions than those of the main stem: flowers solitary, bright yellow: sepals woolly-pubescent, boat-shaped, 6^{mm} long, 6^{mm} broad (if spread out): petals obovate, narrowed to a short claw, 7^{mm} long, 5^{mm} broad, the scale at the base shaped like a wishbone, each part 1^{mm} long: akenes pubescent, orbicular, turgid, with tortuous styles 1^{mm} long, forming a globose head.

FIG. 3.—RANUNCULUS VERTICILLATUS. *a*, plant four-fifths natural size; *b*, petal × 4; *c*, pistil × 4; *d*, sepal × 4.

This interesting species seems to come nearest to *R. affinis* R. Br., but is quite dissimilar to any of the forms of that heteromorphic species.

70. THALICTRUM ALPINUM L. Spec. Plant. 545. 1753.—Stems

scapose from fibrous roots, slender, 1–1.5^{dm} high: leaves all radical, trifoliate, with the leaflets pinnately divided, the segments cuneate, 2–3-toothed at apex: flowers perfect, racemose, on capillary pedicels, from small bracts, erect or pendent: anthers narrowly oblong, mucronate, on capillary filaments: akenes few, pointed.

Type range: "in Alpibus Lapponiae, Arvoniae."

PAPAVERACEAE.

71. PAPAVER NUDICAULE L. Sp. Pl. 507. 1753.—Caudex branching underground: leaves all radical, ovate in outline, pinnately divided, with the three upper divisions confluent, the other two or four entire, or once or thrice lobed, the lobes spatulate, sparingly hispid, with revolute margins, obtuse or aristate at apex; petioles about as long as the blades, together 2–4^{cm}, dilated at base and imbricated, hispid-ciliate: scapes slender, 1–2^{dm} high, more or less hirsute with spreading brown-black hairs: bud elliptical, hirsute with brown-black hairs: flowers bright yellow turning greenish in drying, 2.5–4.5^{cm} in diameter; two petals broader than long, the other two almost orbicular, cuneate at base: capsule brown, 4-ribbed, turbinate-oblong, 10–15^{mm} long, 2–3^{mm} wide at apex, hispid with pustulate hairs: stigma with four glandular-puberulent rays: seeds 1–2^{mm} long, chestnut-brown, glossy, with the outer coat wrinkled and marked with quadrangular venation, having a dark brown spot at one end.

Type locality: "in Siberia." This is a variable species. These specimens agree with none of the described varieties in all particulars.

This species is named *P. radicatum* Rottb. in U. S. Geol. Surv. Reconnaissances in the Cape Nome and Norton bay regions, Alaska, in 1900, p. 170. In *Index Kewensis P. radicatum* is a synonym of *P. nudicaule* L.

FUMARIACEAE.

72. CORYDALIS PAUCIFLORA Pers. Syn. 2:69. 1805; Ledeb. Ic. Fl. Alt. *pl. 450.*—*Fumaria pauciflora* Steph. in Willd. Sp. Pl. 3:861. 1797–1830.—Stem 1.5^{cm} high (the only specimen is in fruit and is without the root): leaves on long petioles, of three palmate divisions, these again 3–4-parted with oblong or obovate

mucronate divisions, glabrous, 3^{cm} in diameter, orbicular in outline: bracts ovate, somewhat keeled: capsules pendent on erect or spreading slender pedicels, 15^{mm} long, equaling the oblong-lanceolate capsules; these tipped with a persistent style 1^{mm} long, and a tufted stigma: seeds orbicular, black, in two rows.

Type locality: "in montibus Altaicis Sibiriae." According to the description and the figure in Ledebour the corolla is purple and long-spurred.

CRUCIFERAE.

73. CARDAMINE BELLIDIFOLIA L. Sp. Pl. 654. 1753.—Caudex branched from a fibrous coated rootstock (the fibers the dry petioles of former leaves): glabrous throughout: stems $4–9^{cm}$ high, slender: radical and lower cauline leaves on long slender petioles, $1–2^{cm}$ long with ovate or orbicular blades $4–6^{mm}$ wide; upper stem leaves sessile or occasionally with short petioles: flowers white, in corymbs lengthening to racemes, on pedicels 3^{mm} long, which become somewhat longer in fruit: sepals generally purplish, with white margins, oblong, about 2^{mm} long: petals white, cuneate, 4^{mm} long, 2^{mm} wide, tapering to a claw: style short and stout: pods too young to describe.

Type range: "in Alpibus Lapponiae, Helvetiae, Brittaniae."

74. **Cardamine Blaisdellii** Eastwood, n. sp.—Rootstock horizontal, slender: glabrous throughout, with erect stems $1–2^{dm}$ high; radical and lower cauline leaves of three to five 2–3-lobed petiolulate leaflets $5–8^{mm}$ broad, the lobes with callous apex; petioles equaling or longer than the blades, flattened; upper cauline leaves with 3–5 oblanceolate entire petiolulate divisions, $5–8^{mm}$ long, callous-tipped: inflorescence corymbose, lengthening to a raceme 9^{cm} long; pedicels flattened, becoming 2^{cm} long: sepals broadly oblong, yellow, margined with white, obscurely 3-nerved, 3.5^{mm} long, 2^{mm} wide, slightly bullate: petals white, broadly spatulate, tapering gradually from the rounded upper part to the base of the claw: immature pods very slender, 2^{cm} long, narrowed at each end, but expanding under the clavate stigma.

This seems to be intermediate between *C. pratensis* L. and *C. purpurea* Ch. & Schl., but is distinctly different from either. The cauline leaves are sometimes simple and solitary.

75. CARDAMINE PRATENSIS L. Sp. Pl. 656. 1753.—Rootstock obliquely ascending: stems glabrous, 1.5–2^{dm} high: radical leaves of 5–7 orbicular petiolulate leaflets, each 5–10^{mm} broad, the upper one largest; petioles long and slender, about 2–3^{cm}; cauline leaves of 11–13 linear-oblanceolate divisions 2–5^{mm} long, 0.5–1^{mm} broad, the whole leaf 4^{cm} long: flowers at first corymbose, lengthening to a raceme; pedicels 7–10^{mm} long: sepals yellow, white-margined, 4^{mm} long, two slightly saccate at base: petals white turning rose-color, obovate, obtuse or obcordate, unguiculate, 10^{mm} long, 4–5^{mm} broad: pods erect, slender, purplish and green, 3^{cm} long, less than 1^{mm} wide; style short.

Type range: "in Europae pascuis aquosis."

76. CARDAMINE PURPUREA Ch. & Schl. Linnaea **1**:20. 1826.—Rootstocks slender, creeping: stems hispid, erect, about 7^{cm} high: leaves few, cauline one or two; radical and lower cauline leaves similar, of three orbicular leaflets, the upper one petiolulate, with three callous teeth or lobes, broadly ovate or orbicular, 8^{mm} wide, glabrous, with margins ciliate; the lateral leaflets smaller, sessile, 3^{mm} wide; petioles 1–3^{cm} long: inflorescence usually subtended by an entire or lobed leaf, corymbose: sepals yellowish, keeled, half as long as the petals, glabrous, the two outer spurred at base: petals purplish, oblanceolate, tapering to a rather broad claw, together 6^{mm} long: pods glabrous, 17^{mm} long, on pedicels 5^{mm} long, beaked with a stout style 1–2^{mm} long.

Type locality: "in insula St. Laurentii."

77. COCHLEARIA OFFICINALIS L. Sp. Pl. ed. 2, 903. 1762.—Stems low, several from a tap root, branching above with one or two divaricate branches: radical leaves broadly ovate to orbicular, entire or obscurely lobed, truncate, cuneate or cordate at base, 5–10^{mm} broad, on petioles 1.5–3.5^{cm} long; upper cauline leaves sessile with auricled base, ovate-oblong, entire or with a few blunt teeth: flowers crowded at the ends of the branches: sepals yellowish, white-margined, spoon-shaped, about half as long as the petals: petals elliptical obovate, white, 6^{mm} long with the claw distinct: stamens with subulate filaments shorter

than the ovary and orbicular anthers: ovary orbicular, tipped with a short style and capitate stigma.

Type range: "in Europae borealis littoribus marinis."

78. DRABA ALPINA L. Sp. Pl. 642. 1753.—Cespitose with branched caudex clothed with the bases of old leaves: leaves all radical, oblanceolate, acute, with prominent midnerve, ciliate on the margin with simple or branched hairs, about 1^{cm} long and 2^{mm} wide: scapes 2.5^{cm} high, pubescent with spreading hairs, slender: flowers two or three in a capitate cluster: sepals oblong-elliptical, greenish, yellow-margined, 2^{mm} long, slightly hairy near the top: petals yellow, twice as long, obcordate, unguiculate: pods not present as the specimens are too young.

Type range: "in Alpibus Europae."

79. DRABA HIRTA L. Syst. ed. 10. 1127. 1758.—Stems several from a branched caudex, canescently stellate-pubescent throughout, about 8^{cm} high, one or two-leaved near the base: radical leaves oblanceolate, about 15^{mm} long, sessile, imbricated at base, callous-tipped, rarely with one or two teeth; cauline leaves broadly ovate, clasping: flowers white, corymbose, on pedicels 2–4^{mm} long: sepals green, white-margined, oblong, acute, 2^{mm} long: petals white, oblong, unguiculate, 5^{mm} long: pods not present.

80. DRABA HIRTA **tenella** Eastwood, n. var.—Stems several from a branched caudex, stellate-pubescent, one-leaved, slender, 6–15^{cm} high: radical leaves oblanceolate, tapering to broad margined petioles, 2–5^{mm} wide, about 15^{mm} long, acute, ciliate with forked hairs; cauline leaf sessile often with one or two blunt teeth: flowers corymbose, pedicellate: sepals oblong-elliptical, white-margined, 2^{mm} long: petals as long again, emarginate at apex, oblanceolate-spatulate, tapering to a claw of half the length: pods on pedicels of about equal length, 7^{mm}, linear-oblong and tapering at each end or lanceolate, glabrous, tipped with a short style and slightly emarginate stigma.

In fruit the raceme often becomes elongated.

81. PARRYA MACROCARPA R. Br. in Parry's 1st Voy. Suppl. to App. 270. 1823.—Caudex branched, covered with white

bleached persistent dilated leaf bases: leaves all radical, narrowly oblong to lanceolate, glabrous, deeply or but slightly dentate, with callous-tipped teeth, tapering to a petiole, together 1.5–5^{cm} long: scape glabrous: flowers corymbose; peduncles and pedicels glandular-hispid, the latter 3–4^{cm} long: sepals purplish, linear-oblong, two spurred at base, the other two hooded at apex: petals white or purplish, obcordate at apex, obovate, tapering to a long claw, together 12^{mm} long: pods 1–5-seeded, veiny, rough-hispid, constricted between the seeds: style 2^{mm} long; stigma 2-cleft: seeds winged, orbicular, 3^{mm} broad.

Type locality: "Melville island."

CRASSULACEAE.

82. SEDUM RHODIOLA DC. Fl. Fr. ed. 3, 4: 386. *pl. 143.*—*Rhodiola rosea* L. Sp. Pl. 1035. 1753; *Sedum roseum* Scop. Fl. Carn. ed. 2. 1: 326. 1772.—Stems erect from a fleshy creeping rootstock, erect, 1–2^{dm} high, leafy, glabrous: leaves fleshy, oblong, serrate: flowers capitate-glomerate, deep reddish-purple, terminating the stem.

Tpye range: "in Alpibus Lapponiae, Austriae, Helvetiae, Brittaniae."

(*To be continued.*)

BRIEFER ARTICLES.

TWO INSTRUCTIVE SEEDLINGS.

(WITH EIGHT FIGURES)

LUBBOCK,[1] in his work on seedlings, mentions not a few examples of lobed cotyledons, and of the appearance on such structures of trichomes of various kinds. The first of these peculiarities he attributes to the need of compact folding in the seed, which may often be of a shape to necessitate such lobing; for the second he gives no reason. A couple of seedlings which I have lately examined show facts which appear to bear directly upon the question both of lobation and of pubescence in cotyledons; these facts I present, together with a slight discussion of what they suggest.

The cotyledon of *Erodium cicutarium* L'Her. (*fig. 1*) has a distinct petiole and an oblique base, the right side, as viewed from above, being constantly higher than the lower. Into the lamina two indentations project, the right one always remaining the more distal. This is the normal condition for the species. But lobing is often carried further than this in the cotyledon, as seen in *fig. 2*, where the form represented is by no means extreme in this respect. Even when extra lobing occurs, the two indentations noted in the normal cotyledon still persist.

The reason for this lobing is perhaps a bit doubtful. Lubbock accounts very well for the oblique character, but seems hardly to make clear the cause of further changes in form, though not only for the species, but also for several others, he mentions them and takes notice of their somewhat inconstant character. To explain this, the slight variation in the shape of the seeds could hardly be regarded as sufficient. There seems, however, to be another view permissible, which may partly, at least, clear up the difficulty, if due care is taken not to press it too far. A glance at the adult plant shows leaves very finely divided, of increasing complexity as one passes from the nepionic, or early seedling leaves, where it is indeed comparatively well-developed,

[1] A contribution to our knowledge of seedlings. 2 vols. 1892.

up to the larger ones of the full-grown individual. Keeping in mind the fact that with the gradual change and increase in complexity of the adult in phylogeny, the representation of past adult stages is pushed further and further back in the ontogeny of the plant, one does not find it at all difficult to carry the idea a single step onward, and to consider the changes in cotyledonar form as influenced by this acceleration in development. Lubbock states that the lobing is perhaps deeper in *E. cicutarium* than in the other species, which are also less lobed or pinnatifid in the adult. As regards the extra lobing in cotyledons of *E. cicutarium*, therefore, I am inclined to adopt the view that acceleration in development supplies the most plausible reason, and to recognize the possibility of accounting thereby for the two constant lobes as well.

That lobation may take place for the sake of compact folding seems, however, fully to be demonstrated by the other seedling with which I am to deal. The genus Amsinckia has deeply parted cotyledons (*fig. 7*), but the following leaves throughout the life of the plant are simple, lanceolate, and entire. Hence it is equally possible that in *E. cicutarium* such lobes as are of a constant nature may likewise be due to this cause, as argued by Lubbock. Researches upon the seedlings of simpler leaved species of Erodium would give interesting evidence upon this point.

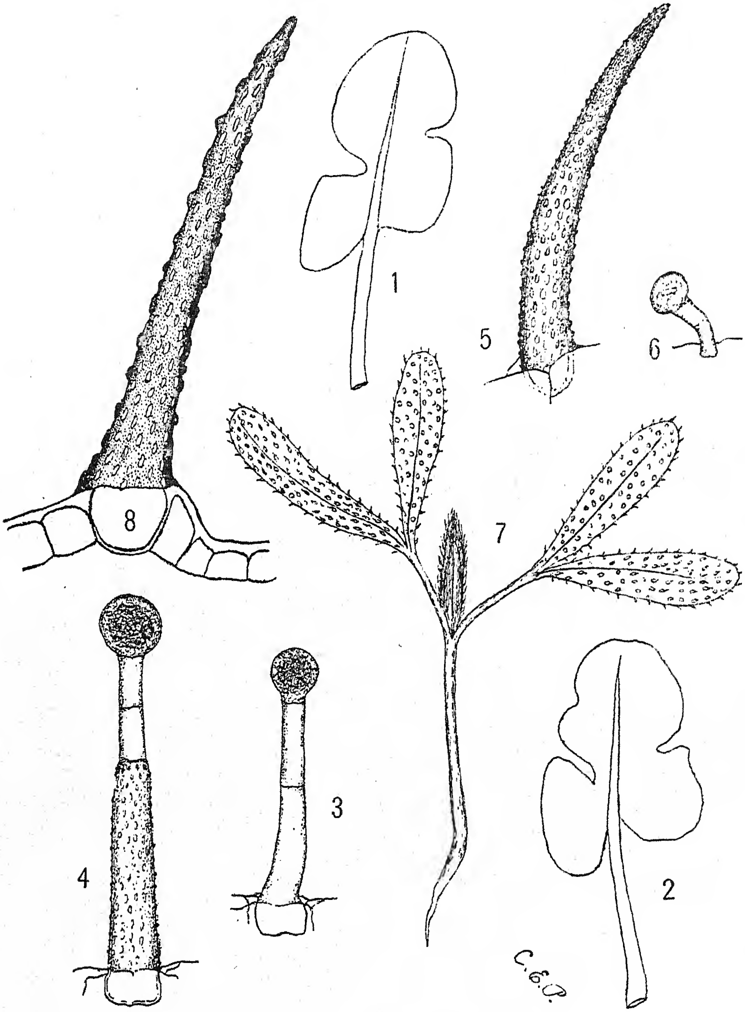
Far more instructive seems the phylogeny of the trichomes in these two seedlings, both of which possess hairy cotyledons. The fact that both Geraniaceae and Boragineae are characterized so generally by hairy plants is in itself significant as pointing out the early appearance of trichome in their phylogeny. The same is also true of the Hydrophyllaceae, where hairy cotyledons are likewise of frequent occurrence. Accepting the views expounded by many writers, among whom may be mentioned Schäffer[2] and Jackson[3] as dealing with the botanical side of the question, viz., that the early leaves of seedlings represent closely the leaves of past adult conditions, we are justified in saying that the trichomes found thereon likewise represent those found on past adults. We therefore gain, in the ontogeny of the plant, a fairly good series illustrating the later phylogeny of the trichome. As

[2] Ueber die Verwendbarkeit des Laubblattes der heute lebenden Pflanzen zu phyletische Untersuchungen. Abhandl. naturwiss. Ver. Hamburg 13 : 36 pp.

[3] Localized stages in the development of plants and animals. Mem. Boston Soc. Nat. Hist. 5 : 89–153. *10 pls.* 1899.

with the lobing, it is easy to suppose that the earlier stages may be thrown back upon the cotyledon.

The examination of *Amsinckia tessellata* Gray, the species used,



FIGS. 1–6, *Erodium cicutarium:* *1*, normal cotyledon; *2*, cotyledon with extra lobes; *3*, glandular hair on cotyledon; *4*, intermediate stage from early nepionic leaf; *5*, trichome of adult leaf; *6*, retrograde gland from adult leaf.—FIGS. 7, 8, *Amsinckia tessellata:* *7*, seedling; *8*, trichome of adult leaf.

brings to light little of importance. The trichome of the adult leaf (*fig. 8*) is large, heavy, and rough warty; that of the cotyledon is already somewhat roughened but is much smaller and less highly tuberculate. *Erodium cicutarium*, on the other hand, shows a definite series of structures, all of which are apparently phylogenetically descended from one of the number.

The hair found on the cotyledon of *E. cicutarium* (*fig. 3*) is glandular, consisting of a round, single celled head, and of two or three stalk cells, the walls of which, even under high power, appear perfectly smooth. No other modified epidermal structures occur in the cotyledons. The glands upon the petiole are similar, often longer stalked.

Upon the lamina of an early leaf may be found structures of three kinds. The first is the gland already described; this, however, is far less common here than on the cotyledons. A second is a modification of the first by the heavy cutinization and roughening of the basal cell (*fig. 4*). This type is usually somewhat larger than the earlier gland. The third structure is a simple, rough warty, pointed trichome (*fig. 5*). On a leaf of this stage the last two mentioned occur in about equal proportions. On the petiole the long stalked gland of the cotyledon seems to maintain its position, but even here the walls of its basal cell begin to show a thickening and more or less of the tubercular character.

In the mature leaf, the simple, unicellular, thickened, and tuberculated point constitutes an almost continuous covering over the surface. The individual trichomes are greatly enlarged and elongated. In addition to this form there is present a smaller number of minute glands (*fig. 6*), short stalked and with heads far inferior in size to those of the cotyledonar glands, these still maintaining the primitive thin walled character. The other forms are almost completely absent.

This series seems to show a variation of the primitive glandular structure along two lines during the phylogeny of the plant. The first of these lines demonstrates the peculiar development, out of a glandular structure, of a simple, rough warty point; the second, the mere degeneration of the stalked gland. The gland of the nepionic leaf (*fig. 4*) seems undoubtedly to be a form intermediate between the primitive gland (*fig. 3*) and the rough warty point of the adult (*fig. 5*), the latter being evolved from the former by the modification of the basal cell and the gradual cessation in development of the upper parts.

In one case I found a poorly developed gland on the tip of a pointed trichome in an adult leaf, but this, though a very instructive intermediate stage, is certainly an exceptional occurrence. As a rule these points are well developed early in the ontogeny of the leaf, and it seems very doubtful whether each one passes through a primitive glandular stage in its development.

As regards the small glands still present, it may be pretty safely concluded that they are a somewhat retrograde condition of the primitive glands. One of such retrograde glands is represented in *fig. 6*, of equal relative size with the other figures of trichomes. These are of much more frequent occurrence on the petiole, where also the stalked glands persisted longest unmodified, than on the lamina. It is also worthy of note that they reach their highest development at an earlier period in the unfolding of the leaf than do the rough warty points, another fact which gives evidence of their direct descent from a primitive structure.—CARLETON E. PRESTON, *Harvard University*

SOME LITTLE KNOWN PLANTS FROM FLORIDA AND GEORGIA.

THE collections made by Mr. A. H. Curtiss during the past summer contain a number of species, which apparently are unrecorded from Florida and Georgia. Among the more interesting of these are the following:

NAJAS CONFERTA A. Br. in Sitzungsb. Ges. Naturf. Fr. Berlin 17. 1868. This species, formerly known only from Brazil and the West Indies, was found abundantly in tidal creeks near Milton at the head of Pensacola bay, Florida, August 3, 1901 (no. 6858.)

FIMBRISTYLIS SCHOENOIDES Vahl. Enum. **2** : 286. An Indian and Australian plant collected by Mr. Curtiss in Walton co., Florida, in 1886, and again on September 23, 1901, by roadsides and in miry spots near Milligan, Santa Rosa co., Florida (no. 6912).

MAYACA FLUVIATILIS Aublet, Pl. Guian. **1** : 42. *pl. 15* (*M. Aubletii* Schott & Endl.) A species described from South America, but found fruiting by Mr. Curtiss in creeks at Milligan, Florida, September 24 (no. 6913). Readily distinguished from *M. Aubletii* Michx. (*M. Michauxii* Schott & Endl.) by its very short thick peduncles.

POEPALANTHUS PILULIFER Koenicke in Mart. Fl. Bras. 3^1 : 426. *pl. 55. fig. 1.* Plants found by Mr. Curtiss in moist cultivated ground

bordering Lake Louisa, Seville, Volusia co., Florida, September 3 (no. 6894), are identified with Koernicke's description and plate.

ATRIPLEX LAMPA Gillies ex Moq. in DC. Prodr. **13**^{2} : 110. A South American species introduced upon ballast grounds near Pensacola (no. 6865).

GALENIA SECUNDA Sond. in Harv. & Sond. Fl. Cap. **2** : 474. A South African plant introduced and now forming broad mats in waste ground about Pensacola (no. 6869).

ILEX DECIDUA Walt. var. **Curtissii.**— Leaves as in the species, but when mature only 1 or 2^{cm} long: berries smaller than in the species, 4 or 5^{mm} in diameter.— Dryish land sloping to the Suwannee river-bottom, Branford, Florida, October 24, 1900 (no. 6736). According to Mr. Curtiss's notes the trees in the neighboring swamp had similarly reduced leaves. Again collected by Mr. Curtiss on Peace river, near Nocatee, De Soto co., Florida, April 13, 1901.

SAPIUM BIGLANDULOSUM Muell. Arg. var. LANCEOLATUM Muell. Arg. Linnaea **32** : 118. A native of Brazil, Argentine Republic, and French Guyana, introduced in waste places at Pensacola (no. 6859).

LECHEA LEGGETTII Britton & Hollick, Torr. Cl. Prelim. Cat. N. Y. 6. In dry pine barrens near St. Marks, Wakulla co., Florida, July 25, 1901 (no. 6847). Rare or unrecorded south of Virginia.

Lythrum Curtissii.—Stems slender, glabrous, prominently 4-angled, ascending and loosely branched above, 6 or 7^{dm} high: leaves glabrous, thin, lanceolate to elliptic-oblong, short-petioled or subsessile; the the primary ones 2 to 5.5^{cm} long; those of the elongated slender branches mostly 1 to 1.5^{cm} long: flowers mostly solitary in the axils: calyx narrowly cylindric, slightly constricted at the throat, strongly ribbed, glabrous, 3^{mm}, becoming 5^{mm} long, the deltoid-subulate lobes somewhat exceeding the bristle-like appendages: petals 6, the oblong-oval limb 2^{mm} long, pale purple with a dark stripe: stamens long-exserted.— In a miry swamp, Leary's, Georgia, August 19, 1901 (no. 6876), and formerly collected in Florida at Aspalaga, October 1897 (*Chapman*, no. 6170 of Biltmore Exsiccatae). Related to *L. lanceolatum* Ell., but of more slender flexuous habit, and with thinner leaves and fewer smaller flowers.

Sabbatia foliosa.— Perennial from elongated slender rootstalks, freely stoloniferous, the simple or loosely branching somewhat flexuous stems 2 to 5^{dm} high: leaves very numerous, 8 to 12 pairs below the lowest flowering branches, lanceolate to oblong-lanceolate, thin and

wide-spreading, essentially uniform to the top of the plant, 2.5 to 6^{cm} long, 0.5 to 1.2^{cm} broad, mostly equaling or exceeding the internodes: flowers solitary and terminal or at the tips of the loosely ascending branches: calyx with 7 to 10 lanceolate foliaceous lobes 1.2 to 2^{cm} long: corolla rose-colored, with 8 to 10 oblanceolate remote lobes 1.3 to 2.5^{cm} long and 5 to 7^{mm} broad.— Swampy thickets on North Edista river, Orangeburg district, South Carolina, August 9, 1884 (*John Donnell Smith*); muddy banks of Blackwater river, near Milton, Florida, July 8, 1897 (*A. H. Curtiss*, no. 5928). Formerly called *S. chloroides* Pursh, from which it differs in its elongated rootstalk and more stoloniferous habit, its thin uniform leaves equaling the internodes, its foliaceous calyx lobes and narrower corolla lobes. From the habitally similar annual *S. calycosa* it differs in being perennial, in its larger usually 10-lobed corolla and narrower more numerous calyx lobes.

Scutellaria glabriuscula.— Stems two to several from a somewhat woody short caudex, slender and arcuate, simple or branching, 3 to 7^{dm} high, minutely puberulent: leaves narrowly oblanceolate, mostly 2 or 3^{cm} long, short-acuminate, narrowed to slender petioles 0.5 to 1.5^{cm} long, all but the lowermost entire, glabrous, viscid and glandular-pruinose: inflorescence racemose or racemose-paniculate, with reduced linear or linear-lanceolate floral-leaves: pedicels 2 to 4^{mm} long, puberulent and occasionally with scattered stipitate glands: calyx glandular-pruinose, minutely puberulent on the angles and margins: corolla 2.5^{cm} long, glabrous, the slender tube and obliquely flaring throat whitish, the lips purplish.— Dry sandy pine-woods, Walton co., Florida, September 15, 1886, and dry scrub lands near De Funiak springs, Walton co., September 21, 1901 (*A. H. Curtiss*, nos. 3, 6907); pine-barrens, Westville, Holmes co., Sept. 18, 1901 (*A. H. Curtiss*). Related to *S. integrifolia* L., but differing from that in its more slender less pubescent stems, narrower slender-petioled glabrous leaves and subglabrous calyx; and from *S. integrifolia* and its immediate allies in its glabrous corolla. *S. integrifolia*, a plant of moist soils, flowers in spring and early summer, while *S. glabriuscula* grows only in dry soil and flowers in autumn.

PERILLA OCYMOIDES L. Gen. ed 6. 578. An Indian species reported by Mr. Curtiss as "abundant in streets of various towns in northwestern Florida and southwestern Georgia. In low woods near Bainbridge, Georgia." Collected August 14, 1901, at Bluff springs, Florida (no. 6874).

PLUCHEA QUITOC DC. Prodr. 5 : 450. Native of Brazil and Chili. Collected by Mr. Curtiss on ballast at Pensacola in 1886, and on August 12, 1901, found established in moist ground near Pensacola (no. 6873).

Cacalia sulcata.—Stem 1 to 1.5^{m} high, deeply furrowed: leaves from ovate to ovate-oblong, glabrous, green on both sides, faintly nerved; the lowest long-petioled, blunt and undulate-dentate; the upper sessile, acuminate, deeply and coarsely acuminate-serrate: corymb broad and loosely branched: the narrowly campanulate involucre of 5 oblong bluntish bracts 8 or 10^{mm} long; the pedicels minutely calyculate-bracted: corolla deeply cleft.—Clearings in edge of swamp near Smithville, Georgia, August 26, 1901 (*A. H. Curtiss*, no. 6884 A). Related to *C. ovata* Ell., but differing in its deeply furrowed lower green stem; green, not glaucous, more cut leaves; and later flowering season—the taller glaucous *C. ovata* with unfurrowed stem flowering some days earlier in the same region.—M. L. FERNALD, *Gray Herbarium*.

THE MORPHOLOGY OF THE PINE CONE.[4]

(WITH PLATE VIII)

SO MUCH has been said in regard to the morphology of the cone of the pine and its near allies that it would seem impossible as well as unnecessary to suggest anything further. However, the recent excellent summary in Coulter and Chamberlain's "Morphology of the Spermatophytes" of the many theories hitherto advanced to clear up the matter, and the conclusions reached by the authors named, show that it is by no means settled, and perhaps warrant me in presenting an interpretation which I have used in lectures before my own classes for half a dozen years or more.

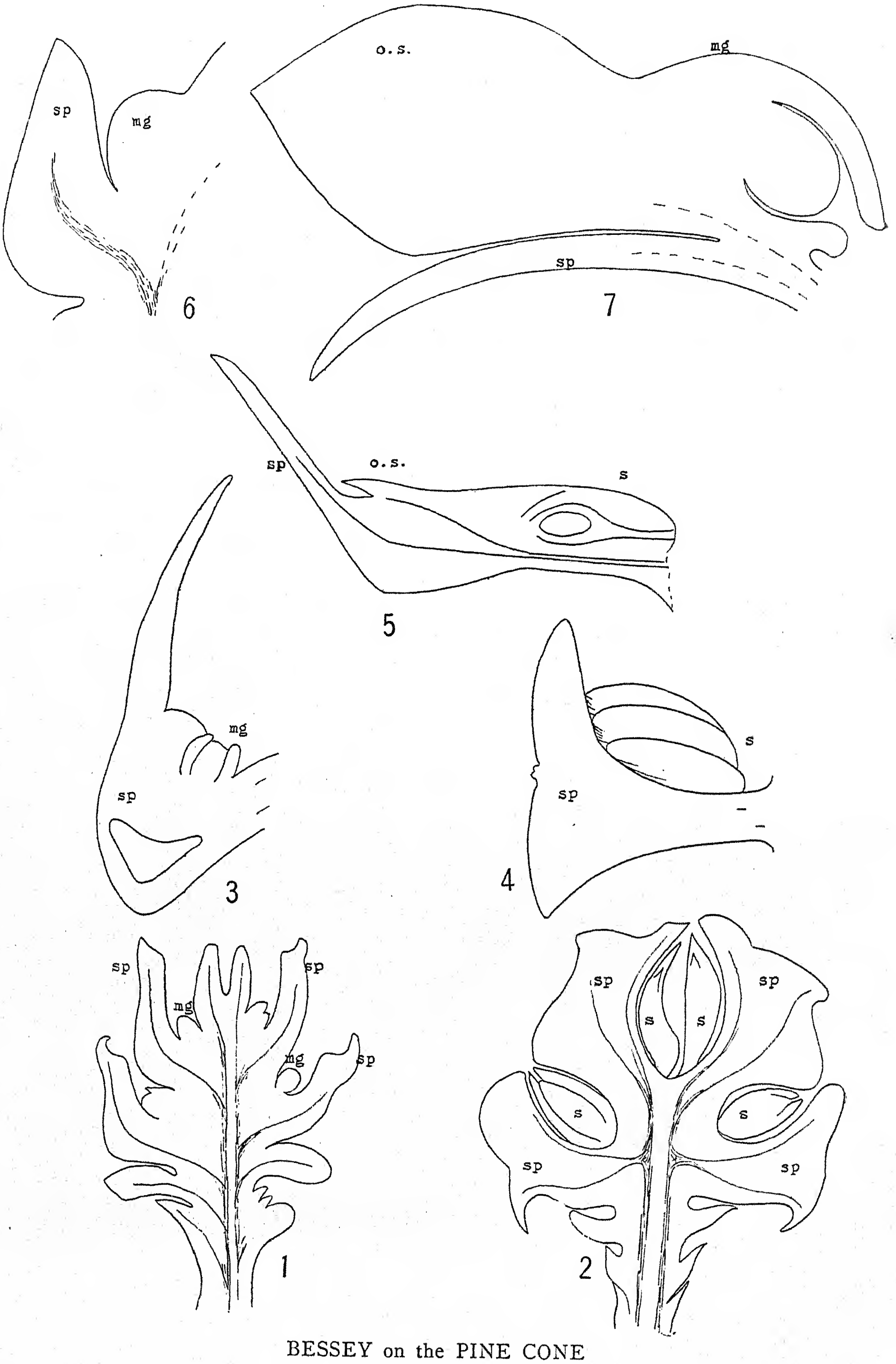
The point at issue is, in short, the morphological nature of the so-called "ovuliferous scale," a structure present in the cones of the Abietineae, but rudimentary or wholly wanting in the other tribes of the Pinaceae. In a pine cone the axis bears bracts which are the homologues of the stamens in the staminate cones, and in addition to these bracts there are thick, woody scales (one immediately above each bract) which bear the seeds. In such a seed-bearing cone the woody

[4] Read before Section G, Botany, of the A. A. A. S., Denver meeting, August, 1901.

scales constitute the bulk of the cone, the bracts always remaining relatively small and inconspicuous. On the other hand, in the cone of a Sequoia, Taxodium, or Cupressus, the whole structure is composed of the enlarged bracts borne upon the axis. On *à priori* grounds there should be no question as to the morphological equivalence of the seed-bearing cones of pines and cypresses, and yet the added structure in the pines — the ovuliferous scale — has brought about a most uncomfortable confusion.

What is this structure? Is it a second leaf, as Robert Brown thought; a flattened axillary stem, as Schleiden thought; a single leaf of a short axillary shoot, as von Mohl suggested; or a fusion of two such leaves, as suggested by Alexander Braun, and accepted by many botanists? Is it a ligular growth as Sachs would have us believe; or is it a vestigial structure resulting from the modification and partial suppression of the axillary stem, as Celakovsky holds? This is not the place for a critical discussion of these views, but I may say in passing that they all fail to homologize the staminate and seminiferous cones.

Many years' study of the young cones of the pines has impressed me more and more with the essential identity of the cones bearing the two sexual cells, and at the same time has suggested an explanation of the origin of the ovuliferous scale which has for several years been helpful to my students. It is noticed that when the megasporangia first appear they are rounded masses of cells pushing up from the axillary region at the base of the bract of the young cone; later, this differentiates into scale and ovule. For a long time the scale portion is composed of chlorophyll-bearing parenchyma, and it is only much later that it becomes brown and woody. At all times there is no line of demarcation between scale and ovule, but the tissues are continuous and pass insensibly from one to the other. These facts led to the suggestion that the scale in the pine cone is a backward extension of the chalazal tissues of the ovules. The scale according to this view is ovular in nature, *i. e.*, it is not a new structure, but merely an enlargement and modification of a structure already present. The cones in the Cupressineae and Taxodieae are normal, *i. e.*, the megasporangia are borne by the bracts (carpels) which later become enlarged. In the Araucarieae the same structural conditions prevail, but while there is a slight backward ovular growth, the bract is still so large as to greatly overshadow it. In the Abietineae the megasporangia, which at first are secondary



BESSEY on the PINE CONE

to the bracts, soon make so great a backward (chalazal) growth as to greatly overshadow the bracts. With the enlargement of the ovular tissue there has been a decreased development of the bract. As the ovular tissue has enlarged it has assumed more and more the photosynthetic and nutritive functions elsewhere discharged by the bract (carpel), until now the latter is practically fuctionless.

Concisely stated this view may be formulated as follows: The microsporangial and megasporangial cones are strictly homologous, and in the latter the sporophyll enlarges or remains small just as the chalazal development of the megasporangium into a scale is less or more pronounced.

In accordance with this view the tribes of the family Pinaceae should be rearranged so as to place the Abietineae at the summit of the group. Probably the sequence would be something like the following:

Tribe I. CUPRESSINEAE.—With Callitris, Thuya, and Cupressus leading to Taxodieae, Juniperus leading off in a side line.

Tribe II. TAXODIEAE.—Leading through Taxodium, Sequoia, and Cunninghamia to the two tribes Araucarieae and Abietineae.

Tribe III. ARAUCARIEAE.—With Agathis lower than Araucaria.

Tribe IV. ABIETINEAE.—With Picea, Tsuga, Abies, etc., lower, and Larix, Cedrus, and Pinus higher.— CHARLES E. BESSEY, *The University of Nebraska.*

EXPLANATION OF PLATE VIII.

FIGS. 1, 2, 5, 7, are from Strasburger's *Die Coniferen und Gnetaceen; fig. 3* from Shaw's *Life history of Sequoia sempervirens* (BOT. GAZ. 21: 332. 1896); *fig. 7* from Coulter and Chamberlain's *Morphology of Spermatophytes; fig. 4* is original. In all the figures *mg* is the megasporangium; *o. s.*, ovuliferous scale; *s*, seed; *sp*, sporophyll.

FIGS. 1, 2. *Cupressus funebris; 1*, longitudinal section of a young megasporangial cone; *2*, longitudinal section of a seed-bearing cone, the seeds nearly mature.

FIGS. 3, 4. *Sequoia sempervirens; 3*, vertical section of a young sporophyll and a single megasporangium; *4*, longitudinal section of a sporophyll with with seeds at maturity.

FIG. 5. *Araucaria excelsa;* longitudinal section of a young sporophyll, with seed and rudimentary ovuliferous scale.

FIGS 6, 7. *Pinus Pumilio; 6*, longitudinal section of a young sporophyll with rudimentary megasporangium; *7*, longitudnal section of an older sporophyll, with megasporangium grown backward as an ovuliferous scale.

A. F. W. SCHIMPER.

BRIEF mention has already been made of the death of this brilliant botanist, but it is fitting to record here some of the most interesting features of his life. In view of his high rank as a botanist and his many contributions to all phases of botanical activity, it seems incredible that he was but 45 at the time of his death. His father before him, W. Ph. Schimper, had made for himself an illustrious name in botanical work, no other of his time excelling him in his two favorite fields, bryology and paleobotany. The subject of our sketch won his doctorate in 1878 at Strassburg, where his father was professor of botany.

Schimper's first famous investigation was on starch and plastids, and he was the first to show that plastids are necessary for starch formation. Another important contribution to knowledge was made when he showed that plastids do not arise spontaneously in the cytoplasm, but that they always proceed from pre-existing plastids. Some years later Schimper published papers on the formation of calcium oxalate in leaves and on the assimilation of mineral salts by green plants, calling attention to the manifold metabolic activities of the leaf, and showing that chlorophyll has a part in the production of proteids.

Botanists have often had occasion to remark Schimper's breadth of mind. Versed in all botanical fields and an investigator in many, he could scarcely be narrow. But it cannot be doubted that his extensive travels, especially in the tropical regions of both hemispheres, contributed largely to his breadth of view. American authors have often complained that continental botanists do not give sufficient credit to papers printed this side of the water, but no such complaint could rightly be made against Schimper. Perhaps his fellowship at Johns Hopkins in 1881, and his travels in Florida, the West Indies, and South America made him feel kindly toward Americans. Some years later he spent considerable time at Buitenzorg, and his investigations are among the most brilliant that have come from that famous botanical center. Only a short time before his death he accompanied the Valdivia expedition to the Antarctic regions.

In 1883 Schimper was called to the University at Bonn, where he rose from a docentship to a professorship, and it was from here that most of his investigations were published. In 1899 he accepted a call to the University at Basel, where he remained until his death, September 9, 1901. Schimper will doubtless be remembered longest through

his ecological contributions. It was he who organized and issued the *Botanische Mittheilungen aus den Tropen*, which have probably done more to give a correct picture of the ecology of the tropical vegetation than all other works combined. Schimper himself contributed the most important papers to this series, among which may be mentioned: Die epiphytische Vegetation Amerikas, in which most of our knowledge about epiphytes as they occur in tropical nature is to be found; Die Wechselbeziehungen zwischen Pflanzen und Ameisen im tropischen Amerika; Die indomalayische Strandflora. One of Schimper's most important papers was on transpiration; in this place he for the first time clearly showed that plants of cold regions and plants of saline habitats are obliged to meet the same dangers as desert plants, viz., excessive transpiration.

The crowning work of this indefatigable botanist was his *Pflanzengeographie*, which was reviewed in this journal.[5] The review written at that time was the result of a first impression. Now that almost daily use has been made of this great work in the three years since it appeared, that favorable impression has been not only fully justified but intensified. It is clear that this work marked, as then predicted, the beginning of a new epoch, an epoch that is expressed in the title: *Pflanzengeographie auf physiologischer Grundlage*. It is the physiological basis that distinguishes the new ecology from that of other days, and into this new field of endeavor Schimper led the way. It is sad indeed that those who are trying to follow out the tortuous ecological paths have lost a leader of such ability and breadth.— H. C. COWLES.

[5] BOT. GAZ. **27**: 214–216. 1899.

CURRENT LITERATURE.

BOOK REVIEWS.

Medicinal plants of the Philippines.[1]

AS INDICATED in the translator's preface, the book is primarily intended to facilitate the study of the native medicinal plants by the numerous medical officers stationed at small posts throughout the Philippines, but it will also prove of great value to botanists everywhere, and particularly to pharmaceutical botanists. The style of the book is simple and very interesting, with an occasional quaint comment. For example, under tobacco, the author says, "The robust who smoke and drink to excess and meet with an accidental death on a railroad or from an acute disease that overtakes them in the midst of robust health, serve as arguments for the defenders (of the tobacco habit) to prove the innocence of the custom." And again, "The antiseptic power of tobacco is undoubted, but it is intolerable that a physician under the pretext of avoiding self-infection should enter the house of his patient and continue smoking at the bedside." As the author admits, much of the information regarding medicinal properties of plants and plant parts is obtained from the Filipino herb doctors (*curanderos*). The common native names are given. The botanical descriptions are simple and quite brief.

The book is timely, and it will assist American botanists to acquaint themselves with the flora of their new possessions.– -ALBERT SCHNEIDER.

Trees in winter.

THE reviewing of so-called popular scientific books is usually unpleasant, because one has so often to say disagreeable things; but in this instance the task is quite the reverse. Miss Huntington's *Studies of trees in winter*[2] will certainly aid very materially in developing a love for nature study.

The book is unique in that it is a guide for the study of our more common trees in a season which, though popularly supposed unsuitable for a study of plants, is one that, as the book shows, has certain very marked advantages. The absence of foliage brings out much more clearly the tree habit, bark

[1] PARDO DE TAVERA, T. H.—The medicinal plants of the Philippines, translated from the Spanish into English by Jerome B. Thomas, Jr., captain and assistant surgeon, U. S. A. 8vo, pp. 269. Philadelphia: P. Blakiston, Son & Co. 1901. $2.00.

[2] ANNIE OAKES HUNTINGTON: Studies of trees in winter. 8vo, xviii + 198 pages, 75 full page half-tone illustrations and colored plates and text cuts. Boston: Knight & Millet. 1902. $2.50.

characteristics, and other details more or less obscured during the summer months. As Sargent says in his introduction to this work, "For the student of trees searching for accurate knowledge it is as important to study trees in winter as in summer." While the book has undoubted scientific value, its great value will lie in its bringing many into a little closer touch with nature.

The half-tone illustrations from actual photographs are remarkably good, bringing out details very clearly, for which no doubt the publishers deserve much credit. The colored plates, in so far as I am able to judge, are true to nature. Print, paper, and binding leave nothing to be desired.—ALBERT SCHNEIDER.

Cellulose.

IN 1895 Cross and Bevan published a large work under the title *Cellulose, an outline of the chemistry of the structural elements of plants.* Although that work was especially intended for chemists, it proved of assistance to physiologists who were concerned with this substance in its structural relations to have the chemical data brought together in a connected way. The same authors now issue a work entitled *Researches on cellulose, 1895–1900,*[3] which is intended as a supplement to the former one. It gives a brief account of those researches which have been published between the dates named, as well as certain of the authors' own investigations not previously published. No attempt has been made to give the subject-matter the form of a connected record. The papers are presented in abstracts, some very brief, some much longer, but all without comment. The book serves well to show the direction in which investigation is proceeding, and also the advances made in technical application of chemical knowledge. It would be well for botanists to familiarize themselves more thoroughly with the chemistry of cellulose. We should then hear less about the cell wall being "composed of cellulose," which, from a chemical point of view, tells as little about it as to say that a house is built of stone tells of its materials or its architecture. The investigations into the cellulose of fungi, the hemicelluloses, lignocelluloses, and pecto-celluloses are contributions to plant physiology as well as to chemistry. In spite of its technical character the book is one which botanical libraries should have.—C. R. B.

NOTES FOR STUDENTS.

V. K. CHESNUT[4] has published a very full account of the plants used by the Indians of Mendocino county, California. The numbers of plants used, and the uses to which they were put, are amazing to those not familiar with the subject.—J. M. C.

[3] CROSS, C. F. and BEVAN, E. J.: Researches on cellulose, 1895–1900. 8vo, pp. xii + 180. London, New York, and Bombay: Longmans, Green, and Company. 1901.

[4] Contrib. U. S. Nat. Herb. 7: 295–408. *pls. 10–21.* 1902.

A CONTRIBUTION from the Leipzig Institut on the function of hydathodes[5] comes to these conclusions: (1) they are not necessary to the plant for the prevention of the injection of the intercellular spaces, since plants do not suffer from injection (though *Impatiens parviflora* sheds a large part of its leaves); (2) they do not render the plant important service in the acquisition of mineral food by hastening the movement of water, for Pfeffer's *Physiology* says that even in the moist climate of the tropics transpiration keeps the leaves supplied! "We may therefore regard the hydathodes only as organs whose presence is now occasioned less by their necessity than by heredity." Since when? — E. B. COPELAND.

N. SCHULZ,[6] in investigating the relations of light to the germination of the spores of mosses, ferns, and equisetums, has reached the following conclusions: (1) these spores germinate only in light; (2) an exception to this rule occurs only in certain ferns that have other biological peculiarities, as ophioglossums, etc.; (3) light is necessary to spores of mosses and ferns as a stimulus to the transformation of the food reserve and to growth; (4) other stimuli cannot replace light in this process except in Ceratopteris, where it may be replaced by raised temperature; (5) in a sugar solution moss spores seem to germinate, but this growth, accompanied by stronger storage of starch and the prominent swelling of the spore, cannot be compared with germination under normal conditions; (6) the spores of equisetums produce cells that are not in resting condition and contain no food, and hence light is not necessary as a stimulus to digestion, but as a condition for photosynthesis.—F. M. LYON.

BLACKMAN AND MATTHAEI[7] have been observing the responses of certain leaves to traumatic stimulation. The leaves of *Prunus Laurocerasus* show remarkable vitality when removed from the plant, remaining fresh for more than a month, while oleander leaves remain fresh for several months, and even put forth roots if placed in water. Portions of old Prunus leaves were killed, and these patches of dead tissue were soon found to be cut off by an absciss layer and exfoliated. The absciss layer involves epidermis and mesophyll, and after exfoliation has occurred cutinization of the exposed parts takes place. When a number of wounds were made close together, a general absciss layer developed around all of these, and live parts as well as dead were exfoliated. In young leaves actual regeneration of new tissues, in distinction to the healing processes just noted, was observed. The authors discuss wound cork and other regeneration tissues, agreeing with Massart and others that suberization is due chiefly to a dry atmosphere.—H. C. COWLES.

[5] LEPESCHKIN, W.: Die Bedeutung der Wasserabsondernen Organe für die Pflanzen. Flora 90: 42–60. 1902.

[6] Beihefte Bot. Centralb. 11: 81–97. 1901.

[7] Annals of Botany 15: 533–546. 1901.

O. Rosenberg,[8] in investigating the pollen of *Zostera marina*, finds that the radially elongated archesporial cells give rise to tapetum on both sides of the sporangium by cutting off isodiametric cells at each end. Some of the primary sporogenous cells form sterile tissue. This is nourishing in nature and is later represented only by free nuclei between the spore mother cells. The long primary sporogenous cells destined to form microspores divide many times by longitudinal walls forming linear pollen mother cells. The tetrad divisions following are also longitudinal, and the second occur before the walls of the first reach the ends of the cells. The nature of these divisions is evidenced by their rapid succession and by the reduction of chromosomes from twelve to six. The remarkable thread-like form of the pollen (2000 by 8μ when mature) prevents the formation of the typical tetrad group, the microspores simply adhering in bundles. The solution of the microspore problem in Zostera is of special interest to morphologists since it clears away the last reported case of the formation of microspores from mother cells without the reduction division.—T. C. Frye.

Nelumbo is certainly a perplexing form. The closed bundles, irregularly scattered, present a distinctly monocotyl feature; the leaves with reticulate venation suggest dicotyls, while the flowers might be either monocotyl or dicotyl. The earlier observers, dealing with mature seeds, have described the embryos of *Nelumbo* and of other members of the Nymphaeaceae as dicotyledonous. The recent work of Mr. H. L. Lyon[9] seeks to establish their monocotyledonous character. Material for the present work was collected in August, 1899, and August, 1900, in southeastern Minnesota, where acres of *Nelumbo lutea* grow in the bayous of the Mississippi river. A study of the development of the embryo shows that it retains a spherical shape until it consists of several hundred cells. The single cotyledon then appears as a crescent shaped organ partly surrounding the plumule. The cotyledon now becomes bilobed by a localization of growth. The first foliage leaf arises on the side opposite the cotyledon. The radicle is transitory and does not develop into a primary root, but the work is done by secondary roots arising from the hypocotyl. The only character which has kept the Nymphaeaceae among the dicotyls is the apparently dicotyl embryo. Since study of its development shows that the embryo is truly monocotyledonous, and since the anatomy conforms more closely to the monocotyls, Mr. Lyons refers the Nymphaeaceae to a subseries coordinate with the Potamogetonaceae, Alismaceae, and Butomaceae in the series Helobiae. A future paper will deal with the development of the embryo-sac and fertilization.—Charles J. Chamberlain.

[8] Ueber die Pollenbildung von Zostera. Meddel. Stockholms Högsk. Bot. Inst., pp. 21. 1901.

[9] Lyon, H. L.: Observations on the embryogeny of Nelumbo. Minnesota Bot. Studies **2**:643–655. 1901.

It has long been known that the internal osmotic pressure of fungus hyphae is much greater when these are grown in concentrated solutions than when the medium is dilute. The question whether this is due to an absorption of the osmotically active substance of the surrounding medium or to an active secretion of other solutes into the cell sap has been taken up again by von Mayenburg.[10] That the internal pressure does not rise by mere inward diffusion of the surrounding solute, at least in most cases, was shown by Eschenhagen, and the present author (who uses *Aspergillus niger*) has corroborated this result by analyses of the fungus body. But in the case of glycerin there is an exception to this rule, as might be expected from the great power of this substance to penetrate most protoplasts. Fungi grown in concentrated glycerin solutions are found to contain this compound in about the same concentration as it occurs in the surrounding medium.

An attempt was made to determine the nature of the internally active substances in the more usual cases, where inward diffusion plays no important part in the rise of turgor pressure. Mineral salts and potassium salts of organic acids are shown to be unimportant in this regard. The author was unable to identify the active substance, but presents evidence which leads him to suggest that it may be some oxidation product of dextrose.

The author suggests that there may be a parallelism between the effects produced by mechanical checking of growth (in higher plants) and those caused by concentrated medium. Both agencies decrease growth and both are accompanied by rise in internal osmotic pressure.— B. E. Livingston.

Several valuable contributions to our knowledge of the process of fertilization have been recently made by Hans Winkler.[11] By an ingenious method this author was able to separate mature unfertilized eggs of the brown alga, *Cystosira barbata*, into two parts, the one nucleate, the other non-nucleate. He observed that sperms penetrate both parts, and that after their entrance both parts divide and produce normal embryos. Cell division, however, is somewhat more rapid when the female nucleus is present.

Winkler was also able to corroborate Morgan's observation that non-nucleate portions of the eggs of the sea urchin, *Echinus microtuberculatus*, will produce normal embryos after the entrance of sperms. The observation is carried further, however. If a non-nucleate portion be cut from an entire normally fertilized egg, this portion may be made to develop a normal embryo by a second fertilization. The experiment no longer succeeds, however, after the first cleavage plane has been formed.

Unfertilized eggs of *Arbacia pustulosa* were made to develop, at least as far

[10] Mayenburg, Ottomar Heinsius von: Lösungs-concentration und Turgorregulation bei den Schimmelpilzen. Jahrb. wiss. Bot. **36**: 381–420. 1901.

[11] Winkler, Hans: Ueber Merogonie und Befruchtung. Jahrb. wiss. Bot. **36**: 753–775. 1901.

as the 16-celled stage, by placing them in an extract of the sperms of the same species. The sperms were extracted both in distilled water and in concentrated sea-water, at a temperature of 70°, which is fatal to them. The extract was brought nearly to the concentration of normal sea-water (by the addition of concentrated sea-water or of distilled water, as the case demanded), and the unfertilized eggs were placed therein. The extract as used had a somewhat higher osmotic pressure than that of normal sea-water, but the author shows that this is not a fatal objection to his experiments, since the same concentration of KNO_3, $MgCl_2$, etc., produced no response in the eggs. Neither did a similar extract made from the sperms of another species have any effect. What is the nature of the chemically active body here demonstrated, the author cannot yet say. He closes the paper with some remarks upon the theory of fertilization.— B. E. LIVINGSTON.

ZACHARIAS[12] has recently made another contribution to the knowledge of sexual cells. Chemical and morphological researches upon the sperm cells of animals and plants indicate that the cilia and spiral bands of plant sperms correspond respectively to the tail and head of animal spermatozoa. The spiral band and the head are distinguished chemically by their nuclein content, nuclein being lacking in the cilia and in the tail. Besides many animal forms, the author investigated the sperms of Nitella, Chara, Ceratopteris, Pellia, Polytrichum, and other plants. The various forms were treated with a solution of sodium sulfate (sodium sulfate 10 gr., acetic acid 1 gr., water 100 gr.). To this solution a little acid fuchsin was added. This sharply differentiates the nuclein-containing portion from that which contains no nuclein, and shows that heads and spiral bands differ in their chemical behavior from tails and cilia. When solution with methyl green instead of acid fuchsin is applied to spermatozoa of the salmon, the head, which contains the nuclein, becomes swollen, while the tail and middle piece become sharply differentiated but do not stain. The tail and middle piece, however, stain well when acid fuchsin is used. When alcoholic material of the spermatozoa of Triton is treated with the fuchsin-containing solution, the tail and middle piece are not at all swollen but become stained, the latter very intensely. The head appears swollen and slightly stained, but the staining may be due to a delicate covering and not to the nuclein-containing content of the head. Living sperms of Chara and Nitella show the anterior and posterior portions of the band not at all swollen but intensely stained, while the middle portion is not at all stained but is very much swollen. Zacharias was able to satisfy himself that the middle piece of Triton and the salmon, as well as the blepharoplasts of Chara and Nitella, contain no nuclein. The term "middle piece" is variously used, but only when it is of centrosome

[12] ZACHARIAS, E.: Beiträge zur Kenntniss der Sexualzellen. Ber. d. deutsch. bot. Gesell. 19: 377–396. 1901.

origin is it to be compared with the blepharoplasts of plants. In some cases he was able to determine that the portion of the male sexual cell which is derived from the nucleus of the mother cell contains a larger percentage of nuclein than the nucleus of the female sexual cell. The investigations of botanists and zoologists have not yet determined the nature of the influence that the sperm exerts upon the egg in normal fertilization, but evidence is accumulating, and the present paper adds some interesting facts in regard to the chemical behavior of the sperm cells of animals and plants.—CHARLES J. CHAMBERLAIN.

ARNOLDI[13] has made another contribution to our knowledge of morphology of gymnosperms. The previous papers of the series have already been reviewed in the GAZETTE. The present paper deals with Sequoia and other members of the Sequoiaceae, namely Taxodium, Cryptomeria, Cunninghamia, Arthrotaxis, Glyptostrobus, and Sciadopitys. As might be expected, in a paper dealing with so many and such inacessible genera, the series are often incomplete, but the results are nevertheless interesting and important. In *Cunninghamia sinensis* there are numerous archesporial cells and several embryo sacs attain a considerable degree of development. In *Sequoia gigantea* the endosperm develops uniformly, thus differing decidedly from *S. sempervirens*, in which the development at the middle of the endosperm differs from that at both ends. The archegonia occur singly or in groups, but are not so numerous as in *S. sempervirens*. There are two neck cells and no ventral canal cell. In Taxodium, Cryptomeria, and Cunninghamia the archegonia are grouped as in the Cupressineae, and have a common jacket, but sometimes there is a layer of endosperm between the archegonia. In Sciadopitys the neck is very peculiar, consisting of from four to eight vertically elongated cells. Proteid vacuoles are present in the archegonium and they probably arise from the jacket cells. These vacuoles are not found in any other members of the Sequoiaceae. No ventral canal cell was identified, but it may yet be found. In Cryptomeria the upper end of the egg becomes mucilaginous, and sometimes separates from the rest of the egg, but no ventral canal cell is formed.

In *Sequoia sempervirens* at the time of fertilization the pollen tube contains two male cells and two free nuclei, one the nucleus of the pollen tube, and the other the nucleus of a disorganized cell which Belajeff called the sterile cell of the generative complex. No vegetative cell of the male prothallium is formed. The body cell contains starch. In *S. gigantea* the pollen tube presses between the endosperm and the nucellus. The pollen tubes of Taxodium and Cryptomeria behave as in the Cupressineae. The

[13] ARNOLDI, W.: Beiträge zur Morphologie einiger Gymnospermen. V. Weitere Untersuchungen der Embryogenie in der Familie der Sequoiaceen. Bull. des. Nat. de Moscow, pp. 1–28. *pls. 7–8.* 1901.

upper part of the egg becomes mucilaginous and presses upon the neck cells from beneath, while an outgrowth from the pollen tube presses from above and forces its way into the egg. In *Sequoia sempervirens* the round male cell becomes elongated, one figure showing it spirally wound, but this may not be the normal form. In Taxodium, however, the spiral form is the usual one, and this is probably the case in Cupressineae also. The form is probably due to the narrow entrance, the male cell having a greater diameter than the neck of the archegonium. The behavior of the chromatin during fertilization is not described.

In *Sequoia sempervirens* the sex nuclei fuse at the middle of the archegonium, then sink to the bottom and divide. Two cells are organized about the nuclei, and the lower nucleus divides again, thus giving rise to a row of three cells, the lowest of which becomes the embryo, and the middle the suspensor. The upper soon disorganizes, and at this stage the embryo appears to consist of two cells. The first division of the embryo is longitudinal. In Cryptomeria and Taxodium the fertilized egg nucleus passes to the base of the archegonium where two or three divisions occur. Cells are formed about the lower nuclei, but the upper ones remain free. Two or three tiers are organized, the lower one or two tiers forming the embryo, and the tier next above the suspensor.

This agrees with Strasburger's account of Juniperus, except that the free cells were not described. Cunninghamia agrees with Taxodium, Cryptomeria, and the Cupressineae. In Sciadopitys the series was very incomplete but enough was obtained to show that the embryology is very peculiar. The earliest stage found shows four free nuclei at the base of the archegonium, as in all the Abietineae. A later stage shows a "rosette," suspensors, and a loose tissue of embryonic cells. The lowest of these cells form the embryo, those next above develop into a second set of suspensors, still leaving some of the embryonic cells between the two suspensor systems. The figures bear some resemblance to Strasburger's figures of Araucaria, but in Strasburger's account the second set of suspensors, as described by Arnoldi, form a cap which is cast off, while the part between the two suspensor systems—or between the suspensor and cap—develops into the embryo. Arnoldi believes that the two species of Sequoia should constitute a family, the Sequoiaceae; that Taxodium, Cryptomeria, and perhaps Cunninghamia should be included in the Cupressineae; and that Sciadopitys is best regarded as constituting a special family, the Sciadopitaceae.—CHARLES J. CHAMBERLAIN.

D. H. SCOTT[14] has published a detailed account of the remarkable fossil

[14] On the structure and affinities of fossil plants from the paleozoic rocks. IV. The seed-like fructification of Lepidocarpon, a genus of lycopodiaceous cones from the carboniferous formation. Phil. Trans. Roy. Soc. B. 194:291–333. *pls. 38–43*. 1901.

Lepidocarpon, of which a preliminary announcement was made in this journal.[15] In 1897 Mr. J. Lomax found in the lower coal measures as trobilus that differed from those of the genus Lepidostrobus in that each megasporangium contained a single large functional megaspore and three aborted ones. No other Selaginella-like fossil had been discovered with fewer than four megaspores of equal size in a sporangium. Moreover, in the same block of stone were found many detached sporangia and sporophylls identical with those of the strobilus, interspersed with seed-like bodies clearly referable to the *Cardiocarpon anomalum* of Williamson. The latter structures differed from the megasporangia of the cone in possessing an integument and a slit-like micropyle. The conclusion suggested itself to Scott and others that Williamson may have been mistaken in identifying the structures as gymnosperm seeds, but on the evidence in hand it was impossible to refer them to a lycopod. In January 1900, Mr. J. Wild found a lycopod cone that settled the matter beyond question. The upper portion of this strobilus bears sporangia identical with those attached to the cone discovered by Lomax. The basal sporangia, however, are invested by an integument with micropyle, and in all respects agree with the organisms described by Williamson as the "seeds" of Cardiocarpon. In addition to the strobili mentioned, fragments and many detached sporangia have been found, enabling the author to give convincing proof that certain of the highest cryptogams bore seeds. In order that this fossil may not be confused with the Selaginella allies having non-tegumented sporangia, the Lepidostrobi, Scott established the genus *Lepidocarpon* to contain these lycopod "seeds."

A very full description of this interesting organism is given. The sporangia are described as elongated sac-like structures, attached by one surface to the sporophyll. The integument consists of a cushion-like upgrowth arising from the upper face of the pedicel of the sporophyll, enclosing the sporangium completely, except for a long slit running its full length. The sporangium wall is like that of Lepidostrobus, but the megaspore wall is said to be much thinner than that of a spore destined to be shed. It is membranaceous in character, but displays reticulations, characters between those of an embryo sac and a shed megaspore. In several instances prothalli quite comparable in structure to those of Isoetes or Selaginella were found. Archegonia could not be identified with certainty. One section of a prothallus displays cells of quite different form occupying the central region. The author tentatively suggests that they may belong to an embryo. This seems highly probable to the reviewer, who has many similar sections of *Selaginella rupestris*, which also is known to bear "seeds." The elongated cells correspond closely to the vascular bundle in its nascent stage, and the group of smaller cells near the apex of the prothallus to the

[15] Bot. Gaz. 31: 279. 1901.

cross section of the young root. The dark cell at the right in his *fig. 23* is in a position with reference to the embryo that corresponds to the archegonium out of which it has grown. The section of the fossil shows no suspensor, but in *Selaginella rupestris* these cells are often difficult to distinguish from those of the surrounding gametophyte. It is interesting to note that the transitional stages between completely tegumented and non-tegumented "seeds" have not been found. Scott suggests that the non-tegumented sporangia may be arrested organisms rather than younger normal stages. This view accords with Bower's recent studies of the sporangia of Selaginella. However, as detached sporangia are not uncommon in the region explored by Messrs. Wild and Lomax, more light may be shed upon them by later study.

The points of likeness between a seed of a spermatophyte and that of a higher cryptogam are (1) the possession of an integument with a micropyle; (2) a single functional megaspore; (3) the retention of the megaspore, involving (4) the detachment of the seedlike organ as a whole and its indehiscent character. The essential distinction between the higher cryptogams and spermatophytes lies in the fact that in the latter pollination takes place on the parent plant. This point has been settled lately in three living species of Selaginella, but in the case of Lepidocarpon no satisfactory evidence has been found. No microspores have been found between the gaping valves of the integument. It may be that Lepidocarpon should be regarded as a seed in a nascent stage of evolution, and that pollination occurred as in the lower cryptogams after the spores were shed. It is the opinion of the author that this discovery in no way affects views held by him previously that the gymnosperms are of filicineous origin, and that their seeds differ too much in detail from those of the lycopods to warrant affinity. Nor does he think any light is thrown hereby upon the origin of the angiosperms. He regards Lepidocarpon as representing a branch of the phylogenetic tree parallel to or perhaps convergent with the spermatophytic phylum, but without genetic connection with it.—FLORENCE M. LYON.

NEWS.

Dr. Büsgen has been called to a professorship in botany at the Forest Academy in Münden.

Science for January 17 contains an interesting exposition of the very unfortunate forestry situation in New York.

Dr. Sándor Mágócsy-Dietz has been called to a professorship in plant morphology and physiology in the Hungarian University at Budapest.

Mr. W. W. Bailey, of Brown University, has been elected president of the Rhode Island Horticultural Society for 1902. He is also botanist to this society.

The Macmillan Co. announce that they are about to publish a *University text-book of botany* by Douglas H. Campbell of Leland Stanford University.

Dr. D. T. MacDougal has gone to Arizona and Sonora to get cacti and other xerophytes for the new greenhouses in the New York Botanical Garden.

Professor John Macfarlane and a party of students from the University of Pennsylvania spent the Christmas holidays in botanical field work in Florida.

M. R. A. Philippi has been elected director of L'Académie Internationale de Géographie Botanique for 1902. The current bulletin of this organization gives a list of members with their addresses.

The committee appointed by chairman Forbes to consider and report to the Naturalists of the Central States a plan for organization includes as its botanical members Drs. William Trelease and John M. Coulter.

The seventh annual meeting of the Vermont Botanical Club was held at Burlington, January 24 and 25. Dr. B. L. Robinson, of Harvard University, addressed the club on "Some recent advances in the classification of flowering plants."

Beginning with the January number, *The Forester* has been merged with *National Irrigation.* The combined journal is entitled *Forestry and Irrigation.* The new journal is to contain more pages than *The Forester* and is to be more fully illustrated.

Recent numbers of *Plant World* and the *Journal* of the New York Botanical Garden contain pleas for the preservation of our native plants,

and announce a gift of $3,000 by the Misses Olivia and Caroline Phelps Stokes to further this desirable end.

IN THE *Journal* of the New York Botanical Garden for January there is an account of the research work in the Garden. The paleobotanical library and collections have been tranferred from Columbia University to the Garden and Dr. Arthur Hollick appointed curator.

PROFESSOR W. F. GANONG has just brought to completion a new laboratory and greenhouse for physiology on the lines of those recommended in his recent laboratory manual. The house is very thoroughly built, and equipped to meet the needs of elementary instruction.

A NEW botanical periodical is announced from Ceylon, *The Annals of the Royal Botanic Gardens, Peradeniya.* This journal will deal with pure and applied botany, particularly in connection with the Ceylon gardens. Exchanges with scientific journals will be made with pleasure.

PROFESSOR JOHN GIFFORD, of the College of Forestry of Cornell University, and Professor W. W. Rowlee, of the botanical department of Cornell University, spent the Christmas vacation in Cuba and the Isle of Pines. They secured a fine set of photographs and considerable herbarium material.

IN *Nature* for January 2 there appears an interesting sketch of the life of Sir J. Henry Gilbert, who died on December 23, at the age of 84. The deceased was best known in connection with the Rothamsted experimental investigations, which have been of great value to the agricultural world.

THOMAS MEEHAN & SONS, the well-known nurserymen of Philadelphia, have established for their employees an evening school of botany with a systematic course of study, under the direct care of Mr. S. M. Meehan, a member of the firm, and Mr. Ernest Hemming, who has charge of the department of herbaceous plants.

THE ANNOUNCEMENT is made of a new geographic periodical, the *Journal of Geography,* to take the place of the *Journal of School Geography,* and the *Bulletin of the American Bureau of Geography.* The new magazine will have a special department of phytogeography in charge of Dr. Henry C. Cowles, of the University of Chicago. Considerable attention also is to be given to economic botany.

FASCICLE I of the *Ohio fungi exsiccati,* containing sixteen numbers, has recently been issued by Dr. W. A. Kellerman of the State University at Columbus. In addition to the usual data, the label contains a reprint of the original description, with citation of the place of publication. This is intended to be helpful especially to students whose library facilities are deficient. The specimens are pronounced of fine quality,

AT THE holiday meeting of the Society for Plant Morphology and Physiology, the following officers were elected: President, Volney M. Spalding,

University of Michigan; Vice-President, Byron D. Halsted, Rutgers College; Secretary-Treasurer, W. F. Ganong, Smith College. The names of Professors C. E. Bessey and W. F. Ganong were suggested to the American members of the Association Internationale des Botanistes for election as members of the general committee when this election is held.

THE COLONIAL MUSEUM of Harlem proposes to commemorate, on June 15, 1902, the 200th anniversary of the death of Georg Eberhard Rumphius, who studied the botany of the island of Amboina, one of the Moluccas, for many years. Arrangements have been made to issue a medal which shall bear on one side a picture of Rumphius, and on the other a view of Amboina. It will be 50 ^{mm} in diameter, and can be obtained in silver for 25 florins or in bronze for 5 florins. It is also proposed to issue a memorial volume.

DR. EDWARD PALMER, the veteran explorer of Mexico, left Washington January 15 for a collecting expedition in the province of Santiago, Cuba. He will obtain the usual number of sets, which will be offered for sale upon his return. Dr. Palmer will be accompanied by Mr. Charles Louis Pollard and Mr. William Palmer, both of the United States National Museum, who will collect plants, mammals, birds, and reptiles for that institution. As the party will pay especial attention to the unexplored mountains in the southern portion of the province it is expected that the scientific results will be considerable.

AN INDEX to volumes I–X of the *Annals of Botany* (1887–96), prepared by T. G. Hill under the direction of the editors, is announced as ready. In preparing it the aim has been to include, in addition to titles and authors' names, the principal subjects dealt with in each paper, including names of all new species, all species which are described, their synonyms so far as they accur in the *Annals*, and all species as to which original observations are recorded. On the other hand, species which are not new, and which are merely mentioned or enumerated without any description or observation being recorded, are omitted. Those who have lamented the absence of an index will welcome this. It will doubtless prove useful, but is liable to be too limited. We have been hoping that the editors would supply a complete index with each volume.

TOM VON POST and OTTO KUNTZE propose the publication of a *Lexicon Generum Phanerogamarum* in which they intend to supply (1) information as to the legal and scientifically correct nomenclature of genera; (2) nomenclatural revision of sub-genera, families, sub-families, and higher groups according to the international code; (3) correct citation of authors since 1737; (4) correct modes of writing names and citations; (5) the most complete list of all single names of genera, both valid names and synonyms; (6) in the second part a numbered systematic list of valid genera which may serve for the arrangement of herbaria; (7) with each valid genus name the number of

species, their geographic distribution, and the sub-genera; (8) the names of fossil genera corrected according to the law of priority; (9) as an appendix, a list of names of cryptogams heretofore altered in accordance with the law of priority.

UNDER the pressure of increased demands upon its space the *Centralblatt für Bakteriologie, Parasitenkunde, und Infektionskrankheiten* has been enlarged and is issued in somewhat altered form. Part I, containing original contributions, will be published in numbers of varying sizes, to avoid dividing a paper, a volume being composed of fifty signatures. The abstracts will be issued in separate weekly numbers of about two signatures. Part II, which embraces chemical and technological bacteriology, instead of being issued fortnightly as heretofore, will also be published weekly in numbers containing two signatures, the form being unchanged. Particular importance hereafter will be attached to the summary reviews of the state of knowledge regarding certain special subjects. Reports from scientific societies and communications from bacteriological institutes will be a feature of the proposed improvement.

THE FIRST number of the *Botanisches Centralblatt* under the new control has been received. M. Bornet discusses the aim of the Association Internationale des Botanistes; the secretary and editor-in-chief, Dr. J. P. Lotsy, gives the history of the new association, with lists of the members and of the special editors. The journal appears in new typographical dress, which notably improves it. With the vigorous editorial boards in various countries, the reviews promise to be more complete and satisfactory than ever before. The *Centralblatt* is commended to the cordial support of American botanists, who are asked to cooperate with the American editorial board by sending promptly to the proper member copies of their publications. A list of the American editors, with the special field of each, was published in our January number. In the list of members of the Association Internationale des Botanistes the United States already leads other countries. Membership in this association, which costs 15 florins ($6.25) entitles one to receive the *Centralblatt* free. To members of the association only, a complete set of the *Centralblatt* is offered at the extremely low price of $36, instead of the original price of $108; certain odd volumes can also be supplied at 50 cents per volume.

FROM ADVANCE SHEETS of the annual report (for 1901) of the Missouri Botanical Garden it appears that although the extreme heat and prolonged drouth of the summer made gardening operations extremely difficult, the losses in the garden were comparatively small; however, further deaths among the trees are to be expected, unless the precipitation during the winter and spring far exceeds the average. 773 new plants were brought into cultivation, making a total of 9,967. 2,948 plants were distributed to hospitals and

schools. An active exchange has been maintained with other botanical establishments. 91,262 persons visited the garden, which was approximately 20,000 more than in any previous year. On each of the only two Sunday afternoons during which the garden is open about 20,000 persons visited it, the visitors on these two days amounting to 45 per cent. of the total number for the year. 16,256 sheets of specimens were added to the herbarium; nearly 7,000 by gift or exchange, 5,544 by purchase. The number of specimens now in the herbarium is estimated at about 365,000. The additions to the library number 929 books, and 254 pamphlets, making a total of 36,000. 1,184 serials are received at the library, of which 101 are purchased and the remainder, issued by 643 institutions, are presented or received in exchange. The gross receipts of the garden were $125,690.73, of which $44,409 were spent for maintenance and improvement of the garden itself.

THE *Comptes Rendus* for December 16 contains the annual announcement of prizes. The strictly botanical prizes have been awarded as follows: The Prix Bordin to Matruchot and Molliard for their work on the action of freezing and the lack of oxygen on cells, and for physiological work on Stichococcus; the Prix Desmazières to Hirn for his "Monographie et Iconographie des Oedogoniacées;" the Prix Montagne to Mazé for his work on the organism of legume tubercles; the Prix de La Fons-Mélicocq to the late Ferdinand Debray for his work on the algae of northern France; the Prix Thore to Patouillard for his taxonomic work on Hymenomycetes. The Prix Gay in physical geography was divided between Franchet and Saint-Yves for their work on the distribution of alpine plants. The Prix Montyon in physiology was awarded to Mirande for his anatomical and physiological studies on the Cuscutaceae.

Among the prizes and subjects for the coming year are the following: the Grand Prix des Sciences Physique for the best work on the formation and development of the egg in Ascomycetes and Basidiomycetes; the Prix Bordin for the best general treatment of double fertilization in the entire group of angiosperms; the Prix Desmazières, open to everybody, for the best treatise on cryptogams; the Prix Montagne for researches on the lower cryptogams.

VOLUME XXXIII NUMBER 3

BOTANICAL GAZETTE

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THE RHEOTROPISM OF ROOTS.[1]

FREDERICK C. NEWCOMBE.

(WITH FIFTEEN FIGURES)

A. INTRODUCTION.

I. HISTORICAL REVIEW.

THE first author to write of the influence of streaming water in directing plant movement was Strasburger,[2] who worked with the creeping plasmodia of the Myxomycetes. Several years later Stahl[3] devoted some time to the consideration of the same subject. Jönsson,[4] however, the year before Stahl's paper appeared, published the first research on the behavior of roots in a stream of water. Jönsson used seedlings of *Zea mays*, *Triticum vulgare*, and *Secale cereale*, finding both primary and secondary roots bending their tips against the stream of water, attaining finally the horizontal position, no matter in what direction the roots were placed when first immersed. The author states that a similar result could be obtained with the roots of other species of plants, but he does not say what other plants he

[1] XXXIII. Contribution from the Botanical Laboratory of the University of Michigan.

[2] STRASBURGER: Studien über das Protoplasma. Jenaisch. Zeitsch. **10**: 406. 1876.

[3] STAHL: Zur Biologie der Myxomyceten. Bot. Zeit. **42**: 145. 1884.

[4] JÖNSSON: Der richtende Einfluss strömenden Wassers auf wachsende Pflanzen und Pflanzentheile (Rheotropismus). Ber. Deutsch. Bot. Gesells. **1**: 512. 1883.

used, if any. Jönsson suspended his seedlings with their roots immersed in water conducted from a hydrant through a trough.

In 1896, I read before the American Association for the Advancement of Science a preliminary account of extensive experiments on the rheotropism of roots of seedlings. An abstract of this paper was published the same year in the BOTANICAL GAZETTE,[5] as well as in the *Proceedings* of the American Association for the Advancement of Science, and was briefly reviewed in the *Botanischer Jahresbericht;* yet it seems wholly to have escaped the attention of the two authors soon to be mentioned. In the preliminary account just cited, seventeen species of plants were reported, eight of them showing positive rheotropism, and nine showing no response to the streaming of the water. It was shown that definite relations exist between velocity of flow and response, that the latent period is influenced by various factors of the environment, that many roots are not responsive to a stream of water, that all roots which did respond were positive, that there are various degrees of sensitiveness in different species. Some attention was given to the nature of the stimulus, and it was suggested that it might be found to be pressure.

Very recently two authors have published papers on the subject of rheotropism. Berg[6] used the same apparatus that Jönsson employed, and another consisting of a basin of water in which he revolved seedlings fastened to a disk. By these means he found the roots of eleven plants to be positively rheotropic, while the root of *Glycine hispida* gave no response, though only three roots of the last species grew suitably for record. He devised a still better apparatus for securing streaming water; this consisted of a basin, to the water in which was given a rotary motion by a jet of water discharged in the basin in a tangential direction. Berg found the latent period of several roots at definite temperatures, and noted that the rheotropic curve began in the third or fourth millimeter zone from the apex of the root.

5 NEWCOMBE: Rheotropism and the relation of response to stimulus. BOT. GAZ. **22**: 242. 1896; Proc. Amer. Ass. Adv. Sci. 1896; Bot. Jahresb. **24**[1]: 74. 1896.

6 BERG: Studien über Rheotropismus bei den Keimwurzeln der Pflanzen. Lunds Universit. Årsskr. **35**[2]: no. 6. 1899.

Juel[7] made use of the same apparatus that I had described in my abstract in 1896—a revolving basin of water in which the roots of seedlings were immersed. He worked with only three plants, *Zea mays*, *Vicia faba*, and *Vicia sativa*. The first two were found unsatisfactory, being irregular in their response, while the third was used for most of the results recorded. All three species were found to be positively rheotropic. No certain evidence for negative curving was found. The positive response for *Vicia sativa* was shown in velocities of current from 36^{cm} per second down to 0.3^{mm} per second. The maximum and minimum limits of velocity were not fixed. Juel experimented also with the location of the sensitive area, covering some root tips with collodion caps and decapitating some roots. In both cases he obtained responses in the streaming water, and concludes that the whole of the growing zone is sensitive; whether the root-tip is sensitive was not determined. As to the nature of the stimulus inducing rheotropic bending, Juel could not decide. When he placed thin cylinders of collodion over his roots, the roots curved as before. He concludes that the stimulus may be pressure, but suggests that the collodion may have allowed a sufficient stream of water to pass through to give the same stimulus as when the root is naked.

It will be seen from the foregoing narration of work accomplished that there are various questions connected with rheotropism still unanswered. Some of these questions will be dealt with in the following pages. Especially will attention be given to the distribution of rheotropism among phanerogams, the sensitiveness of roots other than primary, the sensitiveness of roots of older plants, the relation of response to velocity of current, the latent period, the localization of the sensitive area, and the nature of the stimulus.

II. METHODS.

The majority of plants used in these experiments were seedlings. The seeds were planted in white pine (*Pinus Strobus*)

[7] JUEL: Untersuchungen über den Rheotropismus der Wurzeln. Jahrb. Wiss. Bot. 34: 507. 1900.

sawdust. It was found that any other sawdust at hand would not give straight roots with several of the species. When the seedlings had attained a suitable length, they were removed from the sawdust, fastened to bars of white pine, and the bar was then suspended with the roots immersed in filtered tap-water. The method of fastening the seedlings to the wooden bar is so simple and so preferable to the common practice of pinning, that it may be worth while to illustrate it with *fig. 1*, and to detail it here. A bar of wood differing in diameter according to the size of the seedlings used is clamped in a vise. Two strips of heavy blotting paper are cut the same length and width of the wooden bar. Next, these two strips are dipped in water, and then laid, one covering the other, on the upper side of the wooden bar, and a rubber band is slipped on over one end of wood and blotting paper. The upper strip of blotting paper is raised with the fingers of one hand, while with those of the other a seedling is inserted between the two strips of paper and deposited close up to the rubber band. The upper strip of paper is then lowered upon the other, another rubber band slipped on, so that the seedling is held between the two pieces of blotting paper by two rubber bands, one on each side. The upper piece of paper is again raised, another seedling inserted, and so on till the bar is full.

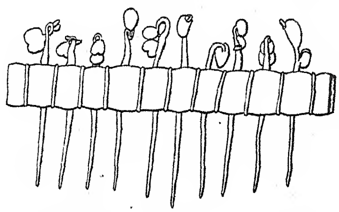

FIG. 1.—Seedlings of *Raphanus sativus*, illustrating the method of fastening to a bar of wood with blotting paper and rubber bands.

The great advantage of this method of suspending seedlings is seen in its avoidance of all trouble from Sachs's[8] curvature. The epicotyl or hypocotyl is left free to carry out this curve without changing the direction of the root. The simplicity and rapidity of preparation commend this method for various kinds of experimentation besides rheotropism. For seedlings whose roots are to be immersed in water, the blotting paper will supply

[8] SACHS: Arbeit. Bot. Inst. Würz. 1: 402.

a suitable amount of moisture, if it is allowed to touch the surface of the water. The wooden bar is wholly unobjectionable if of white pine. I have always taken the precaution of immersing these wooden bars for twelve or more hours in running water before using. I have tested a score of species of seedlings, and have never been able to discover any disturbance of growth having its source in the wood. A heavy bar of glass, with a plane surface for the seedlings might be substituted for the wood.

For many kinds of experiments in which roots are to be immersed in water, it is advisable, as here practiced, to allow the preparation to stand with the roots in water for twelve to twenty-four hours before beginning the experiment; for, with the seedlings of many plants, a few or many roots undergo curves or distortions when placed in water. In my experiments all roots which had deviated from the vertical direction were removed before the streaming of the water was begun.

In most of the experiments here recorded, a flow of water was secured by revolving glass basins full of water on horizontal klinostats and centrifuges. The centrifuges were turned for some experiments by water motors, and for others by an electric motor. The latter gave a constant rate of revolution, so that with it the effect of different velocities could be studied. The apparatus, except the motor, is shown in *fig. 2*. Juel states that in a similar revolving basin which he used, he found the current deviating from the tangential direction, due to the disturbing effect of the opposing roots. To overcome this difficulty he divided his large basin up into four concentric compartments by inserting glass dishes, one within the other. In the most of my experiments, I suspended my seedlings along but one diameter, while Juel suspended his along three diameters. There was more reason for irregular or cross-currents in his basin, therefore, than in mine. I have used basins subdivided into three concentric compartments, and others undivided, and obtained uniformly the same results with both. I made several tests by observing the movement of particles floating in my non-divided revolving basins, and assured myself that the flow as it met the roots was practically uniformly

tangential. To avoid the disturbing effect of the light and change of temperature, the experiments were, in most cases, conducted in a dark room whose temperature was regulated to a variation of less than 2°. The lagging of the current was tested empirically by suspended and immersed particles, and found in all parts of the basin to amount to less than 1 per cent. in velocities of less than thirty revolutions per minute. In the data given in this paper this small retardation will be neglected.

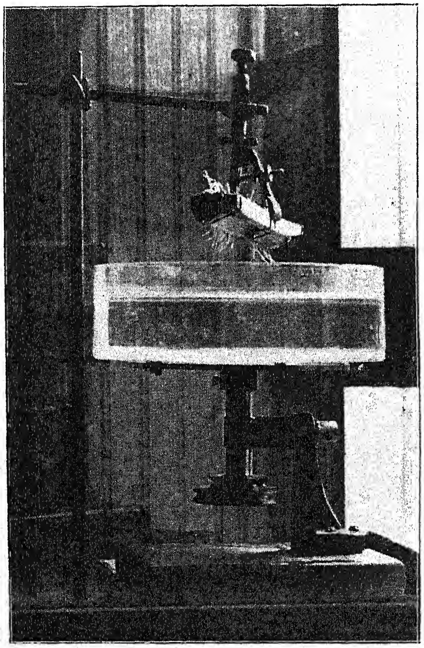

FIG. 2.—A centrifuge and a preparation of seedlings of *Brassica campestris* raised above the water. It will be seen that most of the roots show rheotropic curves of 45° or over, half of the curves being in one direction and half in the other, corresponding to the direction of the water-stream on opposite sides of the basin.

Besides the revolving basin, a narrow wooden trough was sometimes used. The water for this was obtained from a hydrant, and was passed through a gas-heater before being conducted to the trough. A few experiments were made during the night in a brook flowing through a deep ravine.

Various methods employed in the study of special parts of this problem would best not be given here; they will be found in the various sections of this paper.

III. GENERAL PHENOMENA.

The general appearance and progress of the phenomenon of rhetropism in roots are as follows: When plants rheotropically

sensitive have their roots immersed in a current of water of suitable velocity, the roots bend with a greater or less angle against the stream, thus opposing the mechanical effect of the streaming water and the response to gravitation. The angle of curvature in this rheotropic response, as in other phenomena of irritability, is in the growing zone, and there is a definite latent period and after-effect. The angle of curvature in sensitive plants ranges from a few to 90°, thus bringing the tip of the root into the horizontal position. Rheotropism of roots is not a general phenomenon, and great variation in the degree of response is displayed by different species.

B. RESULTS WITH SEEDLINGS.

I. DISTRIBUTION AMONG PHANEROGAMS.

1. *Plants unsuited to experiment.*

Everyone who has made any considerable number of water cultures with seedlings has learned that various species or varieties produce in water only badly contorted primary roots. Obviously such plants cannot be used to any great extent in the study of rheotropism. *Zea mays*, in the four varieties of field and sweet corn employed, showed itself to be practically worthless for experiment with primary roots. The variety of field corn used was a *Western dent;* and of sweet corn, the *White cob*, *Early Minnesota*, and *Old colony*. One hundred and twenty-four individuals of these four varieties were grown in water till the main roots were from a few millimeters to 5^{cm} in length, and none of them produced in still water 30 per cent. of straight roots. In many cases the tip of the primary root was lifted above the water; in others, the root pursued a zigzag course downward; while in others the direction was an irregular spiral.

It is worth noting that Jönssen and Berg for the main part of their work used this erratic *Zea mays*, and Juel employed it to some extent. All three authors, however, call attention to the large number of contorted roots formed. My own results teach that the relatively small number of straight-growing roots

of *Zea mays* (field and sweet corn) are feebly positively rheotropic.

Phaseolus vulgaris, *P. lunatus*, and *P. multiflorus* produce in water better roots than *Zea mays*, but still show a large percentage of contortion. It will be seen later on that these roots are not rheotropic.

Tropaeolum majus, *Pisum sativum*, *Vicia sativa*, and *Lathyrus odoratus* also produce many poor roots in water, though 40 per cent. to 80 per cent. will grow straight.

2. *Plants insensitive to a stream of water.*

Of the thirty-two species of plants tested for rheotropism, fourteen have shown themselves insensitive to the water-stream. These distribute themselves through nine families; while the rheotropic species number eighteen, and are distributed over six families. This result shows that rheotropism of roots is not a general phenomenon. In the narrative of experiments which is to follow, only those details will be given which are necessary to show the basis of the conclusions reached.

Three species of water plants, *Potamogeton perfoliatus*, *Elodea canadensis*, *Ranunculus aquatilis*, were brought under experiment, as follows: From vigorous individuals, apical portions were cut, 10^{cm} or more in length. These cuttings were secured in an upright position to thin glass rods, by tying with thread, and the glass rods were then fastened by rubber bands to a bar of wood 20^{cm} in length, which was suspended in the horizontal diameter of a suitable cylindrical glass aquarium containing water. The bar of wood was wholly above the water, and the lower parts of the glass rods with the plants were submerged. Several aquaria, thus prepared, were set in a south window, and the lower ends of the plants were screened from the direct rays of the sun. Within a week all plants had sent out several to many adventitious roots, the general direction of which was vertically downward. The preparations were then placed upon centrifuges, and the aquaria revolved, while the plants were held at rest in the vertical plane of a diameter. The glass rods and,

to a greater extent, the plants themselves, necessarily disturbed the flowing of the water. But the plants were not more than five in any aquarium, and hence were well separated from one another. Moreover, after the disturbance in passing one radial row of plants, the stream had a full semicircle in which to compose itself before meeting the other radial row. A practical test, made by suspending algal filaments to the roots and watching their trailing, showed that the roots were met by a stream with a constant direction.

Five plants of Elodea were used, and these produced eleven roots in all. Two roots were in streams of a velocity of 628^{cm} per minute, not allowing for the lagging; two in streams of 345^{cm} per min.; and one in a stream of 162^{cm} per min. The revolution continued without interruption for 60 hours, and the temperature of the water varied from 24° to 28°. These eleven roots showed considerable nutation, but none gave any curve in response to the stream, the resultant position of each root being vertical.

Of *Potamogeton perfoliatus* four plants were used. The total number of roots formed was 48. They grew well in streams ranging in velocity from 200^{cm} per minute to 628^{cm} per minute. Constant revolution was maintained for 56 hours in a temperature varying from 24° to 28°, but no curves resulted. The roots were wholly indifferent to the stream.

Ranunculus aquatilis was represented by four individuals, which developed ten roots in all. The revolution continued for 72 hours in a temperature of 24° to 28° in water with the roots in a stream velocity of 188^{cm} to 284^{cm} per minute. The roots showed considerable nutation, but no curves in response to the stream. The nutation, like that in Elodea, consisted of oscillation through an arc often of 45° on each side of the vertical, but in the resultant the roots advanced straight downward, elongating several centimeters during the course of the experiment. In order to clear away any question that may arise at this point as to the suitability of the velocity of stream employed, it may be said that all of the plants which have shown themselves

rheotropic have been sensitive to streams of the velocities given above.

From the results obtained with these three water plants, we may infer that rheotropism is not a general phenomenon with such plants. Possibly it may not be found in any water plant. It would seem to be of distinct disadvantage for such plants to be rheotropic in their roots. For only by insensitiveness to the flow of water can the roots the most quickly find the solid substratum.

Allium cepa was tested both in the bulb and in seedlings. The bulbs used were of the variety known as "multiplier." They were suspended so that the lower end dipped slightly into the revolving dish of water. Three periods of revolution were tried—9 hours, 24 hours, and 37 hours—with the temperature ranging from 16° to 23°, most of the time being above 20°. The velocities of flow ranged from 100^{cm} to 250^{cm} per minute. The number of roots growing well was twenty-eight, and these were most of them 2^{cm} long when the experiment began. In one of the three experiments eight roots bent positively, one negatively, and two grew vertically downward. In the two other experiments, one root bent negatively 90°, while the sixteen others grew in a vertical plane or showed no deviation caused by the current of water. It would thus seem that the roots from the bulb of this variety of the onion are either insensitive or at most but very slightly sensitive rheotropically. Twenty-three seedlings of the onion were tested in streams ranging from 75^{cm} to 600^{cm} per minute, there being continuous revolution for 38 hours, at a temperature of 23.5°. None deviated from the vertical direction, though all grew well.

Nasturtium officinale grows well with roots in water, all pursuing a remarkably straight course downward. Forty seedlings with roots 1^{cm} to 1.5^{cm} in length had their roots subjected to a continuous water stream for 45 hours, at a water temperature of 20.5° to 24.5°, velocity ranging from 100^{cm} to 900^{cm} per minute. All grew vigorously and vertically downward.

Ricinus communis also grows straight roots in water. Of the

twenty-three seedlings used none curved in the water stream. Ten roots were in revolving water for 20 hours, and thirteen other roots for 48 hours, in temperature from 19° to 24°, in velocities from 150^{cm} to 1200^{cm} per minute, without one curve of any kind appearing.

Quercus alba was hardly sufficiently tested. Only six seedlings were tried, and no root of these was rheotropic. The duration of the experiment was 48 hours, the roots elongating 1^{cm} to 2^{cm} in that period. The velocity of the current was 225^{cm} to 600^{cm} per minute.

Cucurbita pepo and *Citrullus vulgaris* grow primary roots very straight in an environment of water. Of the former species, forty-four seedlings have been used in five different experiments, in which the water temperature ranged from 17° to 23°, the velocity of current from 150^{cm} to 2000^{cm} per minute, and the duration of the experiments from 13.5 hours to 9 days. In none of these was any deviation from the vertical shown.

In *Citrullus vulgaris* thirty-one seedlings were employed in three experiments, the water temperature in two being 21° and in the third 24°. The revolution of water lasted in two for 17 hours, and for the third 24 hours. The velocity of current was from 100^{cm} to 1300^{cm} per minute. Only three slight positive curves were formed. In such a very slight result it may be assumed that the bending was not a response to the current, and hence *Citrullus vulgaris* may be accounted non-rheotropic.

Phaseolus vulgaris, *P. lunatus*, *P. multiflorus*, *Glycine hispida*, and *Dolichos lablab* have all shown themselves non-responsive to the flowing of water. The three species of Phaseolus and Dolichos produce many crooked roots in water; Glycine mostly straight roots. In all these experiments the contorted roots have been excluded from the results, and only those showing themselves straight after standing for 10 to 24 hours in still water were used subsequently in the flowing water. The smallest number of seedlings employed in any species was ten, and the largest forty-seven, with a total of 137. The water temperature in some cases was held constant throughout the

experiment, and in others varied from 17° to 25°. The period ranged from 8 to 36 hours. Dolichos showed a very few roots inclined positively, and it is possibly rheotropic in a very low degree.

3. *Plants with a low degree of sensitiveness.*

It has already been intimated that the roots of the bulb of *Allium cepa*, and the primary roots of *Dolichos lablab*, may be slightly positively rheotropic. It is quite certain that the primary roots of the seedlings of *Vicia faba*, *Lathyrus odoratus*, *Lupinus albus*, and *Tropaeolum majus* are positively rheotropic, but only in a comparatively low degree. Juel, in several tests with seedlings of the small-seeded variety of *Vicia faba*, had trouble in controlling the Sachs's curvature. He obtained varying responses and a considerable number of non-responsive roots. He finally concluded that the roots were rheotropic, and bent more readily when so placed that the median plane of the seedling was parallel with the current rather than transverse.

My own experiments were not troubled with Sachs's curvature because of my method of securing the seedlings, and my results agree in a general way with those of Juel, though my plants were mostly of the variety known as "Windsor broad." Apparently, however, this variety is less responsive than that used by Juel, since, as will be seen, the Windsor broad shows many individuals as neutral, while it would be inferred from Juel's narrative that very few of his roots were neutral. Thus, among thirty-seven selected seedlings in four experiments with revolving basins of water, water temperature 19° to 23°, velocity of current 100^{cm} to 2500^{cm}, seventeen grew positively, three negatively, and seventeen were neutral. In two experiments, in each of which nine seedlings were suspended with their roots dipping into a brook of water in a wooded ravine in August, the average temperature being about 23°, all eighteen roots remained vertical, though increasing in length from 1^{cm} to 2^{cm} in the period. In the one experiment the period was 24 hours, and the velocity 450^{cm} per minute; in the other, the period was fourteen hours, and the velocity 900^{cm} per minute.

In a variety of *Vicia faba* with seeds 1.5^{cm} long and 1^{cm} broad, perhaps the same used by Juel, twelve seedlings were placed under experiment with the revolving basin, water temperature 21°, velocity 300^{cm} to 750^{cm} per minute, and period 24 hours. Six roots then showed positive curves from 15° to 90°, and the other six were vertical.

As to the relative degree of response shown by the seedlings when the median plane is parallel to the current of water and when the median plane is transverse, my results, and probably those of Juel, are too few to account as of great importance. In one experiment with six seedlings, with the median plane transverse to the current, four roots out of six responded positively, the greatest angle being 30°. In another experiment with ten seedlings, the median plane being parallel to the current, eight roots bent positively, two of them reaching an angle of 80°. In a third experiment with twelve roots, out of nine with the median plane parallel, four bent positively, while out of three with the median plane transverse, two bent positively. Thus it is shown that the root will respond to the water meeting it on any part of its circumference.

The low grade of responsiveness of *Vicia faba* to a current of water is shown not only in the fact of approximately 50 per cent. of the roots remaining neutral, but also in the exceedingly protracted latent period, and in the small angle attained in most curves. Thus in the experiment with the twelve seedlings of the small-seeded *Vicia faba* with a water temperature of 21°, no roots curved in the first 5 hours. In 8 hours four had curved positively, in 16 hours five had curved, and within the following 8 hours one more curved. Of the twenty-three positively curved roots in both varieties of *Vicia faba*, only three attained angles greater than 45° degrees from the vertical. The majority of curves were below 30°.

Lathyrus odoratus and *Lupinus albus* are, at least in some varieties, positively rheotropic. The latter was found rheotropic by Berg. Both these species produce fairly straight roots when growing in water. With water temperature from 21° to 24°

during a period of 24 hours, only three roots curved out of fifteen seedlings of mixed varieties of *Lathyrus odoratus*. In another group of twenty seedlings, in water temperature of 20° to 22°, only three or four weak curves showed after 24 hours, but fourteen good positive curves showed after 48 hours. Of the others, two were negative and four remained vertical. In a small-seeded variety of *Lupinus albus*, at a water temperature of 27°, sixteen seedlings in the revolving basins of water gave no curved roots during the period of 29 hours. A later experiment with a large-seeded variety, temperature in the water being 17° to 23° and the period 25 hours, gave twenty-two positively curved primary roots in a total of twenty-four. Each of the curves attained an angle of 45° or over. The velocities employed in the experiments with both these species extended from 50^{cm} to 500^{cm} per minute.

It is evident, therefore, that both these species have sensitive primary roots. Whether the varying sensitiveness observed was due entirely to the different varieties, or, in part, to temperature, to different seasons of the year, or to some other condition, was not determined. Enough testing was done to show that it was not due to difference in the water used in the experiments.

Tropaeolum majus behaves badly in water, 25 per cent. to 50 per cent. of the roots becoming contorted. In two experiments, with a total of thirteen straight roots, the period of revolution for one being 12 hours, and for the other 18 hours, the temperature of the water being 22° to 23°, and the velocities ranging from 225^{cm} to 625^{cm} per minute, no roots responded. In another experiment, same temperature, velocities from 100^{cm} to 900^{cm} per minute, twenty seedlings were used. No curve appeared for 6 hours; but at the end of 30 hours, fifteen of the primary roots were positive 15° to 19°, while the other five were pointing vertically downward. The secondary roots gave no certain response. There was considerable irregularity in the direction of growth, but, at the end of the period, the fifteen primary roots showed plainly that this species gives a rheotropic reaction.

4. *Plants with a high degree of sensitiveness.*

It has already been stated (p. 183) that in 134 individuals of four large-fruited varieties of Indian corn so many primary roots grew contorted in water that these plants are wholly unsuited for experiment. At the same time it is to be remembered that Jönsson, Berg, and Juel have found *Zea mays* rheotropic, though none of them states the variety used.

If instead of the large-fruited varieties of *Zea mays* we experiment with the dwarf *Zea mays*, with the white popcorn, we shall soon find this variety in its primary root highly sensitive to a current of water. Quite unlike the contorted roots of the field and sweet corn, the primary roots of the popcorn nearly all grow straight in water. In a total of seventy-nine seedlings in velocities of water of 25^{cm} to 1000^{cm} per minute, period 36 hours, and water temperature 19° to 23°, fifty-seven primary roots showed positive curves, six negative curves, and sixteen roots were neutral. A few of the negative curves were doubtless caused by the mechanical effect of the strongest current employed. The percentage of positive roots is here made but seventy-two, about the same as that of *Vicia sativa*. But many of the angles attained by the roots of the popcorn approximate 90° from the vertical, as shown in *fig. 3*. The general behavior of this seedling is so much better than that of *Vicia sativa*, that we are justified in according it a higher degree of responsiveness.

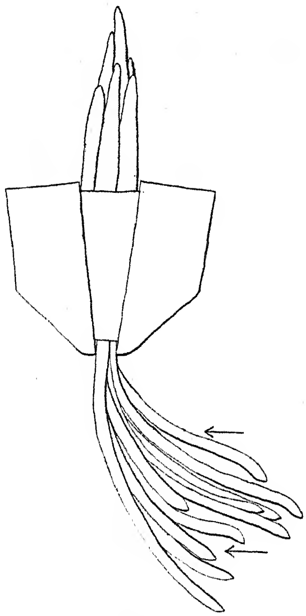

FIG. 3.—*Zea mays* (popcorn). End view of a row of ten seedlings after being in the water stream for 11 hours. The general direction of the roots is more than 45° from the vertical, and the tips of several are nearly 90° from the vertical. The drawing shows the actual size of the preparation, the seedlings growing from a wooden trough and being held in position by packing of cotton wool.

The Gramineae other than Zea, so far as studied, are also positively rheotropic. *Triticum vulgare* and *Secale cereale* were so determined by Jönsson, *Hordeum vulgare* and *Avena sativa* by Berg. In my experiments all four of these species were treated as already described for other plants. After the grains had been placed in the vertical position in sawdust, and there sprouted, they were secured in the vertical position, by means of strips of blotting paper and rubber bands, to the sides of wooden bars extending parallel with the diameter of cylindrical glass basins, and so placed that the lower ends of the grains just met the contained water. Here the preparation rested till the roots had attained a length of one or more centimeters. The revolution was then started. At once the question arises as to how these roots should be judged; for, as is well known, the roots of the cereals grow out in a bunch of several to many secondary members which do not all take the vertical direction till a considerable length is reached. The method finally found the most satisfactory was as follows: When a record was to be made the observer sighted horizontally along the row of roots, counting all roots positive whose apical portion deviated from a vertical plane in the direction against the stream, all roots negative that deviated from the vertical in the direction with the stream, and all roots neutral whose tips were in a vertical plane parallel with the row of seedlings. In placing the grains in position on the supports care was taken to arrange them so that about an equal number met the water current on the flanks, on the front, and on the back. Thus it would seem that there could be no objection to the method employed for judging of the rheotropism of these plants. An error in calling a root positively rheotropic that was only inclined against the stream because of its plagiotropic position would be counterbalanced by calling a root a negative that was inclined in the opposite direction, solely through its plagiotropism, provided the number of individuals employed was large. The results will show such a preponderance in favor of rheotropic response that there can be no question of the fact.

In *Triticum vulgare* ninety-three roots were observed, divided among three experiments. Temperature of the water was from 19° to 22°, velocity from 75^{cm} to 750^{cm} per minute (constant for any one root), period 24 hours for two experiments, and 48 hours for the third. Twenty-five roots were positive, three were negative, and sixty-five were neutral. The angles attained were not more than 20° from the vertical. This would seem to place the wheat among those of weak response to a current of water.

Secale cereale furnished sixty-two roots for observation, temperature of water 20° to 23°, velocity 100^{cm} to 1000^{cm} per minute, period of 15 hours. Fifty-nine roots were positive and three neutral. Several of the angles attained were 90°.

Hordeum vulgare had 102 roots under experiment in a water temperature of 20° to 22°, a velocity of 50^{cm} to 750^{cm} per minute, and periods of 7, 9, and 24 hours. Of positive roots there were eighty-four, negative seven, and neutral eleven.

Avena sativa was tested in five experiments with a total of 132 roots. The water temperature was 21° to 25°, the velocity of current 50^{cm} to 1000^{cm} per minute, and the period 9 hours to 33 hours. Ninety-seven roots bent positively, six negatively, and twenty-nine remained neutral. Many of the roots bent to an angle of 60°.

The four species of Gramineae just considered resemble one another in the production of good roots in water, in displaying positive rheotropism, and in producing a considerable percentage of neutral roots. The wheat shows the smallest number of responses of these four plants.

Of the Leguminosae, ten species have been studied, five being found non-responsive, and five responsive. All but the two most sensitive species have already received attention.

Vicia sativa was pronounced by Juel very sensitive to a stream of water. This author had not tried the much more sensitive Cruciferae. In my experiments *Vicia sativa* has proved itself relatively slow and weak in its response. It responds better than *Vicia faba*, but much less readily than a dozen other plants whose behavior is to be described later.

The experiments with *Vicia sativa* may be divided into two groups: those of a duration of 6 hours to 12 hours, and those of 48 hours. Forty-seven seedlings have had their roots stimulated by currents of water ranging in velocity from 150^{cm} to 750^{cm} per minute, water temperature 19° to 25°, period from 6 to 12 hours, giving twenty positive and twenty-seven neutral roots. Had the revolution of the basins of water been continued longer, it is certain that other roots would have become positive, as is shown by the following results: Eight seedlings had their roots subjected to the streaming of water in a revolving basin for 48 hours, water temperature 18° to 21°, velocity 450^{cm} to 500^{cm} per minute, giving seven roots positive and one negative. In another experiment, out of thirteen seedlings only two showed curves after 12 hours' revolution of the basin, while after another 12 hours ten roots had become positive. It is safe to assume that over 75 per cent. of the roots of *Vicia sativa* are responsive to the flowing of water, whereas only 50 per cent. of those of *Vicia faba* are responsive.

Both of these species are alike in the long duration of the latent period and in the smallness of the angle of curvature. It is certain that in my experiments with these two species, in a water temperature of 20° and an air temperature of 21.5° or higher, more than half the roots to respond rheotropically have shown the first curving later than 8 hours. Not 15 per cent. of those responding have shown a curve earlier than 6 hours. The greatest angle that any of my seedlings of Vicia has attained is 70°; the most of them have reached a deviation of 10° to 25°. *Fig. 4* shows a tracing from a photographic reproduction of the seedlings in one of the foreging experiments, and, with the restriction contained in the description accompanying the figure, is fairly representative of the behavior of this plant.

Pisum sativum resembles in its general behavior *Vicia sativa*. A number of its roots grow crooked in water, its latent period is long, and a considerable number of its roots are non-responsive. It shows, however, a higher percentage of curvatures in response to the stimulus, and the angle attained by the roots is greater

than in *Vicia sativa*. In this series the temperature was kept constant throughout at 23° in air, almost the optimum for the growth of this species and variety; the velocity ranged from 50^{cm} to 1380^{cm} per minute and the period from 16 to 22 hours. Of the ninety-four roots used, seventy-four bent positively, ten negatively, and ten grew vertically. Of the seventy-four positive roots, sixty-one attained an angle between 45° and 90°; several reached 90°.

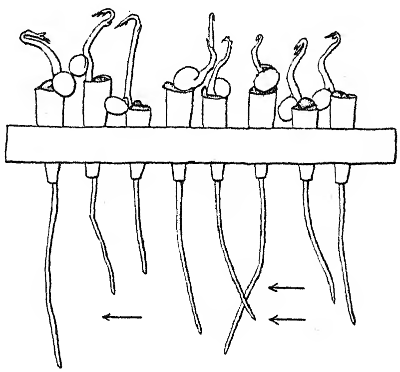

FIG. 4.—Tracing from a photograph, half natural size, of *Vicia sativa*. The seedlings were packed in glass tubes with cotton wool, and the tubes held in holes in a wooden bar. In order to secure a photograph to show the curves to best advantage, the bar was suspended parallel to the water-stream. It was found, however, that the resulting curves were not so great as when the row of seedlings extended, as usual, transversely to the stream. The smaller angles attained were probably due to the interference of the roots with the stream. This figure is presented principally for the purpose of comparing the sensitiveness of this species with that of *Raphanus sativus*, as shown in *figs. 6* and 7, page 198. As is not unusual in this species, the figure shows one root with a negative curve.

Among the Polygonaceae only *Fagopyrum esculentum* has been put under experiment. The primary roots of the buckwheat are evidently highly sensitive, but they show some inclination to form sudden curves in still water. Even though the roots grow irregularly in water, the contorted roots will bend their tips against a stream a short time after it is started. Twenty-six straight roots were selected for experiment. The temperature during the three experiments was respectively 21°, 18°, and 22° in the air. The velocity ranged from 75^{cm} to 750^{cm} per minute, and the periods were 24, 18, and 12 hours. Twenty-four roots became positive, and two negative. My notes record the angles of only seventeen of these twenty-six roots: thirteen bent positively to an angle of 90°, one to an angle of 15°, and two bent

negatively to an angle of 90°. The last two, and perhaps some others, evidently curved, not because of the stream, but because of their objection to the water environment, whatever this objection may be. The relatively large number of positive roots, however, warrants us in concluding that this species is rheotropic.

Of the Compositae only *Helianthus annuus* has been used. Forty seedlings have been tested for a period long enough to determine their rheotropism. The temperature was 21° to 23° in air, the velocity 50^{cm} to 1000^{cm} per minute, the period 17 to 33 hours. Twenty-eight roots bent positively, six negatively, and seven were neutral. The roots bending positively did not attain as great an angle as those of Fagopyrum, less than one-half passing beyond 45°. The roots of Helianthus do not all grow straight in still water, and this behavior will account for the relatively large number of negative curves in the experiments.

The Cruciferae have furnished by far the best material for the study of rheotropism. Of the six species studied, five are rheotropic, only *Nasturtium officinale* showing itself wholly indifferent. The white mustard, the black mustard, the turnip, the cabbage, and the radish, but especially the first and the last of these five, give splendid examples of rheotropic roots. All of the Cruciferae tried produce straight roots in water. In size, the seedlings used were from 2^{cm} to 4^{cm} in length at the beginning of the experiment.

Brassica alba is one of the best of the eighteen species that have been found rheotropic. In five experiments with the revolving basins of water, in which fifty-one seedlings were used, with a velocity of 50^{cm} to 1000^{cm} per minute, a water temperature of 19° to 22°, and a period from 6 to 21 hours, forty-five roots bent strongly positively, the majority being over 45°, and many being 90°. Six roots were neutral. This gives a percentage of 88 and marks the white mustard as a remarkably good plant for experiment. Its great heliotropic sensitiveness requires that the experiments for rheotropism be carried on in the dark. *Fig. 5* shows the curves obtained in one experiment with this plant.

Brassica nigra responds more slowly than *Brassica alba* but attains almost as good a percentage, and almost as great angles. The sensitiveness of its roots to light requires that it, too, be kept in the dark in determining its rheotropism. Twenty-nine seedlings were used in two experiments with the revolving basins, the water temperature being 24°, the velocity 50^{cm} to 450^{cm} per minute, and the periods 9 hours and 15 hours. Twenty-four roots became positive and five remained neutral. In the experiment with the longer period, all of the roots that became positive, numbering fifteen, were 45° to 90° from the vertical. The result gives us 83 per cent of responsive roots.

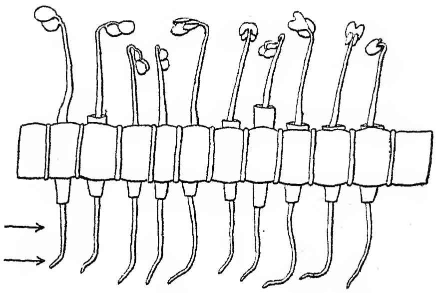

FIG. 5.—*Brassica alba*. A tracing from a photograph, three-fourths natural size. These seedlings were set in glass tubes in order to facilitate transfer for purposes of photographing. During the experiment the bar was held in a radius of the revolving basin for 18 hours, water temperature 21°, the range of velocities being 125^{cm} to 600^{cm} per minute. At the conclusion, the seedlings were twisted around through an arc of 90° in order to show their angles in the photograph. The figure is fairly representative, except that the tips declined slightly during the preparation for photographing.

Brassica campestris was tested in two experiments with a total of forty-two seedlings, water temperature 24°, velocity of current 60^{cm} to 560^{cm} per minute, period 24 hours, giving thirty-six positive curves averaging 45°, three negative curves, and three neutral roots. This gives a percentage of eighty-five positive roots. It will be noted that that the angle attained in these experiments is rather small. It may have been due to the rather high temperature. *Fig. 2* shows the result obtained in one experiment with this plant.

Brassica oleracea was tested in two experiments, water temperature 24°, velocity 60^{cm} to 560^{cm} per minute, and period 20 hours. Thirty-four seedlings were used, of which thirty-two curved positively to an angle of 15° to 80°, while two curved

negatively to an angle of 20°, giving a percentage of ninety-four positive roots.

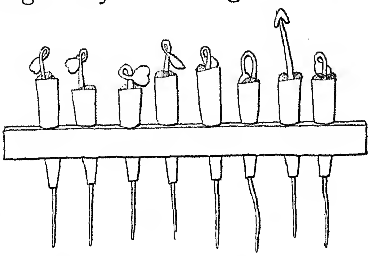

FIG. 6.—*Raphanus sativus* before the beginning of the experiment which gave the result in *fig. 7*. Tracing from photograph.

Raphanus sativus, the variety known as the "early long scarlet," has been for me the best of all plants for experiments with rheotropism. It is larger than any of the other Cruciferae worked with, and for that reason less liable to injury in handling. Its roots are insensitive to light, and hence experiments with it may be conducted in the general rooms of the laboratory. In the series described here, 140 seedlings have been used in nine experiments with the revolving basins of water. The water temperature has ranged from 20° to 25°, the velocity from 50^{cm} to 750^{cm} per minute, and the period from 5 to 33 hours. One hundred and twenty-three roots have bent positively, the majority from 45° to 90°; eight have bent negatively, and nine have grown vertically. The positive roots are, therefore, 87 per cent. The response of this plant to the water stream is relatively very ready. Two hours from the beginning, at a suitable temperature, well marked curves can be detected in 25 per cent. to 50 per cent. of the roots. The relative response of this plant and of *Vicia sativa* is well shown by comparing *figs. 4* and *7*.

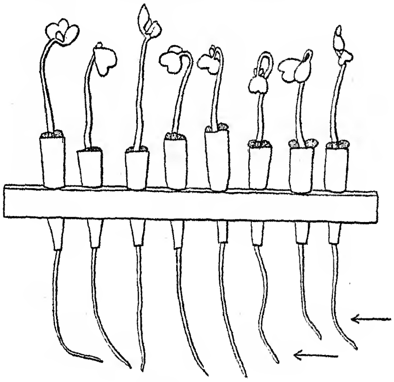

FIG. 7.—*Raphanus sativus*, tracing from a photograph. This figure is to be compared with *fig. 4*. The two give fairly well the relative response of *Vicia sativa* and *Raphanus sativus* in similar conditions. The experiments for both were carried on at the same time, the period of revolution being 23 hours, the temperature in water 19° to 22°, and the range of velocities 100^{cm} to 500^{cm} per minute. As stated under *fig. 4*, these preparations were made for photographing, and the curves are smaller than they would have been had not the bar of seedlings been held parallel with the stream of water.

[*To be continued.*]

A DESCRIPTIVE LIST OF THE PLANTS COLLECTED BY DR. F. E. BLAISDELL AT NOME CITY, ALASKA.

ALICE EASTWOOD.

[*Continued from p. 149*]

SAXIFRAGACEAE.

83. CHRYSOSPLENIUM TETRANDRUM Fries. Bot. Not. 193.—Leaves reniform, crenately 5-lobed: flowers green, inconspicuous: in fruit the carpels separate, showing the tiny red seeds, each of which is fastened to the walls of the capsule by a slender, very short funiculus. The entire plant is perfectly smooth and less than 1^{dm} high.

Comparison made from description by Dr. J. N. Rose, in BOT. GAZ. **23**: 275.

84. PARNASSIA KOTZEBUEI Cham. & Schlecht. Linnaea **1**: 549. 1826.—Scapes $6–15^{cm}$ high, slender, usually with a cauline leaf near the base: leaves clustered at base, ovate to orbicular, on petioles once or twice the length of the blade (that on the stem leaf very short): sepals oblong, a little shorter than the petals: petals white, 3–5-nerved, elliptical: stamens with filaments varying in length, shorter than the petals; anthers orbicular, notched at each end, more deeply so at base; staminodia yellow, 3–5 united, inserted at the base of each petal: capsule surpassing the persistent floral organs; stigma sessile, of four spherical lobes.

Type locality: "in insula Unalaschka ad Sinus bonae spei, Escholtzii et St. Laurentii."

85. PARNASSIA PALUSTRIS L. Sp. Pl. 273. 1753.—Scape slender, $6–20^{cm}$ high, with one cauline leaf below the middle, sessile and cordate clasping: radical leaves on slender petioles, orbicular-ovate, obtuse, usually cordate at base: sepals linear-oblong, callous-tipped, half shorter than the petals: petals sessile, broadly elliptical, white, 5-veined, obtuse or emarginate at apex: staminodia 16, united and unguiculate; stamens with filaments varying

in length, shorter than the petals, linear-attenuate; anthers elliptical: capsule purplish, with the stigmatic lobes recurved.

Type range: "in Europae uliginosis."

86. SAXIFRAGA ADSCENDENS L. Sp. Pl. 405. 1753.—A low, small-flowered species, with the small rosulate radical leaves pedately 3-cleft: flowers panicled, the peduncles stipitate-glandular below, glandular-puberulent above: petals slightly surpassing the obtuse sepals, white, and with noticeable parallel venation.

Type range: "in Pyrenaeis Baldo, Tauro Rastadiensi."

87. SAXIFRAGA BRONCHIALIS L. Sp. Pl. 400. 1753.—Matted at base with low slender stems rising from a rosulate tuft of leaves; these linear, acute, with conspicuous white-ciliate margins; stem leaves linear, appressed: flowers yellowish-white, dotted with yellow, smooth except for a few scattered short gland-tipped hairs: petals oblong, unguiculate,

This is quite unlike the plant of the Rocky mountain region which has been included under this species.

Type range: "in Sibiria."

88. SAXIFRAGA COMOSA Britton Mem. Torr. Bot. Club **5**: 178. 1894. *Saxifraga stellaris comosa* Poir in Lam. Encycl. **6**: 680. 1804.—Scape slender, sparingly glandular-villous, about 8–12^{cm} high, naked up to the little bunches of leaves which take the place of flowers: flowers when present terminating the scape: calyx with minute, roundish, purple divisions: petals with oblong blades, white with two yellow spots at base, truncate or cordate at base, oblong, acute, 3^{mm} long; claw one-third as long as the blade: stamens with flat linear-acuminate filaments, shorter than the petals; anthers suborbicular, dark purple: leaves in a cluster at base, broadly oblanceolate, toothed at apex, sparingly ciliate with bristly hairs.

89. SAXIFRAGA FLAGELLARIS Willd. ex Sternb. Rev. Saxifrag. 25, *pl. 6.* 1812; Hook. Fl. Bor.-Am. **1**: 253. *pl. 87.*—A well-marked species, sending out long filiform runners which root at the ends: dead leaves densely imbricated on the caudex, obovate-spatulate, conspicuously ciliate; upper leaves and stem

glandular: corolla bright yellow, with obovate petals about 1^{cm} long.

90. SAXIFRAGA HIERACIFOLIA Waldst. & Kit. Pl. Rar. Hung. 1: 17. *pl. 18.* 1802–1812; Hook. Fl. Bor.-Am. 1: 249.—This belongs to the group which includes *S. nivalis* L., and is distinguished by black-purple flowers which are interruptedly spicate-glomerate. The pollen is bright orange. The scape is clothed with viscid-arachnoid jointed hairs, and sometimes has one leaf. Radical leaves elliptical-oblong, with margined petioles and crenate margins.

91. SAXIFRAGA HIRCULIS L. Sp. Pl. 402. 1753.—Stems matted at base, clothed with oblanceolate, dead, brown leaves: leaves few on the stem, clothed with jointed arachnoid brownish hairs: flowers few on each stem: petals yellow, linear-oblong, obtuse, about 1^{cm} long, the lower half generally orange-dotted.

This is a beautiful and showy species.

Type range: "in Suecia, Helvetia, Lapponia, Sibiria."

92. SAXIFRAGA OPPOSITIFOLIA L. Sp. Pl. 402. 1753.—Stems prostrate, creeping: leaves imbricated in fours, fleshy, ciliate, with a pore in the center of each near the apex: stem one-flowered, 12^{mm} high, one-leaved: capsule surpassing the divisions of the calyx: stamens shorter than the petals, which in the specimens examined were withered.

Type range: "in rupibus Alpium Spitzbergensium, Lapponicarum, Pyrenaicarum, Helveticarum."

93. SAXIFRAGA PUNCTATA L. Sp. Pl. 401. 1753.—Leaves all radical, reniform, crenate-dentate: flowers small, white, at first capitate-corymbose, later in fruit becoming panicled: white petals ovate with cuneate base, retuse apex, and punctate with tiny numerous close dots: pubescence viscid-arachnoid with the hairs on the upper part of the stem gland-tipped: follicles tinged with purple, divaricate, tipped with sessile stigmas: the specimens are variable in size, from 5^{cm} to $1–2^{dm}$.

Type range: "in Sibiria."

94. SAXIFRAGA RIVULARIS L. Sp. Pl. 404. 1753.—A small-flowered species with many low stems from fibrous roots: leaves

3–5-lobed, very small, cuneate at base, the pubescence arachnoid with woolly viscid hairs: flowers few, terminating the slender branches: calyx often with purple-tipped divisions: petals white, tinged with purple, oblong, veiny: stigmas sessile, divaricate.

Type range: "ad Alpium Lapponicarum latera et rivulos."

95. SAXIFRAGA RICHARDSONIANA Hook. Fl. Bor.-Am. 1:247. 1840.—About 3^{dm} high, with orbicular-reniform leaves $2.5–5^{cm}$ broad: petioles, scapes, and lower surface of leaves clothed with scattered black glands, leaf margins doubly dentate: flowers large, in racemes that become spiciform: acuminate sepals purplish, with few gland-tipped hairs: petals white, unguiculate, obovate-elliptical, abruptly acuminate, twice as long as the sepals.

This is beautifully figured in *Botany Beechey* under the name of *S. Nelsoniana* H. & A., p. 124. *pl. 29.*

ROSACEAE.

96. COMARUM PALUSTRE L. Sp. Pl. 502. 1753.—Stems erect, with few compound leaves, each consisting of 5 oblong-obovate leaflets with deeply serrate-dentate margins, green on the upper surface, pale beneath: all parts of the flowers red-purple, the petals much shorter than the sepals.

Type range: "in Europa uliginosis."

97. DRYAS OCTOPETALA L. Sp. Pl. 501. 1753.—This beautiful plant is widely spread through both parts of the northern hemisphere, forming mats: leaves oblong, pinnately lobed with oblong lobes, hairy, margins revolute, veiny and glossy on the upper surface, white tomentose on the lower: corolla white, 2.5^{cm} in diameter: calyx with narrowly linear divisions clothed with black hairs: fruiting akenes tipped with feathery styles resembling those of Pulsatilla.

Type range: "in Alpibus Lapponicis, Helveticis, Austriacis, Sabandicis, Hibernicis, Sibiricis."

97*a*. DRYAS INTEGRIFOLIA Vahl. in Scriv. Naturh. Selsk. Kjoeb. 4: 11. 1798.—Similar to the preceding, but with leaves narrower, the margins entire and revolute.

98. GEUM ROSSII Seringe, DC. Prodr. **11**: 553. 1825. *Sieversia Rossii* R. Brown, Parry's First Voy. App. 276. 1824.—Stems clothed at base with the brown sheathing petioles and stipules of dead leaves, glabrous below, 3^{cm}–3^{dm} high, 1 or 2-flowered, with some bract-like leaves scattered along the flowering stem: leaves interruptedly pinnate, the larger divisions irregularly lobed at the top, the smaller ones much smaller, entire: calyx open-campanulate, often brownish-red, pubescent: corolla yellow, 2^{cm} in diameter, with the petals suborbicular, obcordate, veiny: stamens numerous on filiform filaments inserted on the calyx: pistils with very slender straight styles and akenes hispid with upwardly spreading hairs.

Superficially this resembles some species of Potentilla.

99. POTENTILLA BIFLORA Willd. ex Schlecht. in Gen. Naturf. Fr. Berol. Mag. **7**: 297. 1813.—Caudex clothed with brown broad sheathing stipules: leaves with linear, revolute divisions, hairy on the margins and lower surface, and with a tuft of hairs at the apex: scapes 1–2-flowered: calyx appendages linear, narrower than the ovate divisions, almost equaling them in length: petals obcordate, with the base a deeper yellow than the upper part: akenes glabrous, reddish at summit and tipped with long reddish styles, at base beset with long hairs which give the receptacle a woolly appearance.

100. POTENTILLA FRUTICOSA L. Sp. Pl. 495. 1753.—A widely distributed species, and easily distinguished from the other species by its shrubby habit. The akenes are woolly, and the corolla yellow, 2^{cm} in diameter.

Type range: "in Eboraco, Anglia, Oelandia, Australi, Sibiria." This has been segregated from Potentilla by P. A. Rydberg as Rafinesque's *Dasiphora* (Mem. Dept. Bot. Columb. Univ. 7: 188).

101. POTENTILLA UNIFLORA Ledeb. Mem. Acad. Petersb. **5**: 543. 1812.—Cespitose, the caudex clothed with brown dry stipules: leaves cinereous on the upper surface, densely white-tomentose on the lower: leaflets 3, palmately wedge-shaped, 3–5-cleft: flowers 1 or rarely 2 on the stem: calyx white-hairy, with bractlets almost as broad and long as the ovate-lanceolate

divisions: corolla with obcordate petals, glabrous, veiny, keeled on the back with a sharp margined ridge: styles shorter than the akenes.

King mountain.

102. RUBUS ARCTICUS GRANDIFLORUS Ledeb. Fl. Ross. 2:70.—Stems low: leaves trifoliate, with the leaflets cuneate and entire at base, dentate from below the middle to the apex: flowers rose-color, 2–3^{cm} in diameter.

Type locality: "in America arctica ad sin. Kotzebue."

103. RUBUS CHAMAEMORUS L. Sp. 494. 1753.—Low, with leaves simple, orbicular-reniform in outline, 3–5-lobed, and margins irregularly dentate: flowers white, 2^{cm} in diameter.

Type range: "in Sueciae paludibus uliginosis, turfosis frequens."

104. SANGUISORBA MEDIA L. Sp. Pl. ed. 2. 169.—Stems erect, 3–4^{dm} high: leaves mostly radical, compound with 9–11 petiolulate leaflets, the lowest pair smallest, oblong-ovate; the largest 3^{cm} long, and almost 2^{cm} wide, coarsely dentate, glabrous, paler on the lower surface, often tinged with purple; cauline leaves 3 or 2, with fewer and narrower leaflets; stipules dentate: flowers in a dense spike 1–2^{cm} long, purple.

Type locality: "in Canada."

105. SPIRAEA BETULAEFLORA Pall. Fl. Ross. *pl. 16.* 1784–1788.—Low shrub, with slender erect branches clothed with reddish-brown bark: leaves on short petioles, broadly oval, crenate-serrate except near the base, glabrous, paler on the lower surface: corymbs sessile: flowers small, white, 6^{mm} in diameter: stamens much exserted: sepals reflexed, deltoid: follicles pubescent on the line of dehiscence, tipped by styles of almost equal length.

Type range: "in Sibiria orientali ad fl. maja."

LEGUMINOSAE.

106. ASTRAGALUS ALPINUS L. Sp. Pl. 760. 1753.—This pretty little Astragalus is readily recognized by the capitate flower-cluster on a long peduncle, with the flowers and pods pendent:

the calyx and pods are clothed with black hairs: the corolla is white tinged with rose-color: leaflets small, canescent.

Type range: "in Alpibus, Lapponicis, Helveticis."

107. **Hedysarum auriculatum,** n. sp.—Stems 2–3^{cm} high, generally with two or three flowering erect branches, striate, appressed downy-pubescent: leaflets 9–13, petiolulate, lanceolate, aristate, 1–2.7^{cm} long, about 5^{mm} wide, veins prominent, lower surface with scattered pubescence, upper glabrous; petioles very short or wanting; stipules brown, sheathing, membranous, 2-cleft to below the middle with divisions attenuate: racemes 5–13^{cm} long, on long peduncles, with flowers pendent on recurved pedicels; bracts deciduous, linear-attenuate; bractlets narrowly linear, close under the calyx: calyx with one large subulate tooth opposite a broad sinus, the other four equal and shorter, about half as long as the tube, hairy pubescent on both surfaces: corolla rose-color, 12^{mm} long; keel 1^{cm} long, auricled at base, obtuse at apex; claws 4^{mm} long; wings linear, three times as long as the claws, less than 2^{mm} wide; banner obovate, emarginate, 1^{cm} long, 5^{mm} wide: pods consisting of 2–4 orbicular to oblong joints, glabrous, margined, veiny, 5–10^{mm} long.

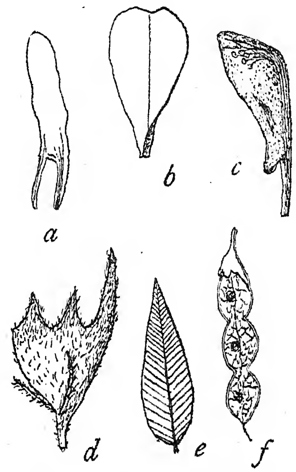

FIG. 4.—*Hedysarum auriculatum*: *a*, wing, × 2; *b*, standard, × 2; *c*, keel, × 2; *d*, calyx, × 5; *e*, leaf, nat. size; *f*, pod, nat. size.

Along the banks of streams.

108. **Hedysarum truncatum,** n. sp.—Stems erect, 2–2.5^{dm} high, slender, striate, subcinereous with scattered white hairs: leaflets 9–11, short-petiolulate, oval to ovate-lanceolate, mucronate, 10–15^{mm} long, veins prominent, pubescent a little on the midrib and margins; stipules brown, membranous, sheathing, with two attenuate apices: racemes 1 or 2, generally on peduncles about 6^{cm} long: flowers pendent, rose-color, 17^{mm} long:

calyx with two divisions subulate, one-third as long as the tube, densely hairy on both sides, thickened on the midrib: corolla glabrous; keel 1^{cm} long, twice as long as the claw, truncate at base, obtuse at apex; wings linear-oblong, eight times as long as the claws; standard cuneate, obcordate at apex, 15^{mm} long: pods with 1–3 joints, which are glabrous, reticulate, orbicular-oval, becoming 6^{mm} or more long, and margined all around.

This is near *H. alpinum* Willd. as delineated in Bot. Reg. *pl. 808.* It differs in pubescence, shape of leaflets, truncate keel, and fewer joints to the pod. Scattered over the tundra.

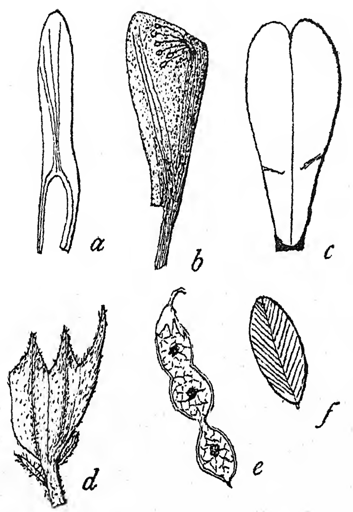

FIG. 5.—*Hedysarum truncatum:* *a*, wing, × 2; *b*, keel, × 2; *c*, standard, × 2; *d*, calyx. × 5; *e*, pod, nat. size; *f*, leaf, nat. size.

109. OXYTROPIS LEUCANTHA Pers. Syn. **2**: 331. *Astragalus leucanthus* Pall. Astragal. 59. 1800.—The specimens collected were in flower only: flowers yellow, in short oblong heads terminating the one or two scapes: caudex densely clothed with dead brown stipules and petioles: leaves and scapes cinereous with appressed hairs mixed with occasional longer ones; the pubescence of the leaves chiefly on the margins and midrib: calyx densely clothed with long black hairs mixed with a few white ones.

According to the description in Gray's revision in *Proc. Am. Acad.* **20**: 1–7, the flowers of the specimens seen by Dr. Gray were "well suffused with violet." These are distinctly yellow, without a tinge of violet. It may be some other species, or perhaps new.

Type locality: "in Sibiria."

110. OXYTROPIS MERTENSIANA Turcz. Bull. Soc. Mosc. 68. 1840; Ledeb. Fl. Ross. **1**: 584.—Leaves 3–5 or solitary: flowers purple, in 2–3-flowered heads: calyx clothed with black or brownish hairs which are also on the erect pods: pod shortly

stipitate, the ventral suture intruded so as to almost divide the pod into two cells.

Type locality: "in terra Tschutschorum ad sinum St. Laurentii."

EMPETRACEAE.

111. EMPETRUM NIGRUM L. Sp. Pl. 1022. 1753.— A heather-like prostrate shrub, forming dense beds a few centimeters high, with small crowded linear thick-keeled glossy leaves about 2–4^{mm} long: young stems and leaf margins glandular: midrib sunken on one side, invisible on the other: flowers inconspicuous and solitary in the upper axils: sepals and petals 3, purplish: stamens 3, exserted: pistillate flowers with a globose ovary surmounted by a short thick style having 6–9-toothed segments: fruit a blue-black berry known as "crow berry" and "heath berry."

The minute glands on the younger stems and margins of the leaves seem not to have been noted in any description seen by me, though these glands are to be found on all the most northern plants in the Herbarium of the California Academy of Sciences.

Type range; "in Europae frigidissimae montosis paludosis."

VIOLACEAE.

112. VIOLA BIFLORA L. Sp. Pl. 936. (1753).—Stems slender, ascending: leaves round-reniform, obtuse or acute, 1–2^{cm} wide, somewhat pubescent; lower ones on long petioles; upper ones on petioles but little longer than the blades; margins crenulate-denticulate, ciliate; stipules green, ovate-acuminate: flowers 1 or 2, yellow marked with brown lines on the largest petal, which is 1^{cm} long: sepals linear-subulate, 3–4^{mm} long; spur blunt, short: capsules pubescent: seeds mottled with brown, with a prominent rhaphe at the pointed end.

Type range: "in Alpibus Lapponiae, Austriae, Helvetiae, Angliae.

113. VIOLA PALUSTRIS L. Sp. Pl. 934. 1753.— Rootstock slender, creeping: leaves round-reniform, all basal, obscurely crenulate, glabrous; petioles generally shorter than the 2-bracted, 1-flowered scape: sepals ovate, white margined: corolla white, about 1^{cm} long, the lowest petal veined with purple, all without

beard in the throat; spur short, rounded, of about equal length and breadth.

Only two specimens were collected, both in flower, and not good.

Type range: "in Europae frigidioris paludibus."

ONAGRACEAE.

114. EPILOBIUM LATIFOLIUM L. Sp. Pl. 347. 1753.—Stems less than 2^{dm} high, generally ascending, leafy to the base, minutely puberulent throughout, and somewhat canescent on the younger parts: leaves sessile, opposite or alternate, ovate-elliptical or lanceolate, with scattered callous teeth on the margin; midrib evident, but other veins obscure: flowers axillary or in racemes with leaf-like bracts on pedicels as long as the ovary: buds at first erect, then pendent, and again erect before anthesis: sepals crimson, linear-acuminate, shorter than the petals, 2^{mm} wide: petals a lighter shade of crimson, rhombic-ovate, somewhat unequal, about 2^{cm} long, and almost 1^{cm} wide, tapering at both ends: capsules erect spreading, 6^{cm} long, purplish, tapering at each end with the apex truncate: coma tawny.

Type range: "in Sibiria."

115. EPILOBIUM SPICATUM Lam. Fl. Fr. 3:482. 1778.—Entire plant glabrous: stems about 5^{dm} high, with the lower leaves scale-like: upper leaves opposite or verticillate in threes, lanceolate-acuminate, revolute with a few gland-like teeth along the upper margin, about 6^{cm} long, sessile at base, veiny: flowers in racemes, reflexed in bud, with the lower bracts leaf-like; upper ones minute; pedicels spreading, a little shorter than the ovary: calyx lobes crimson, oblanceolate, mucronate: petals obovate, 7^{mm} long, surpassing the calyx lobes, crimson: stamens 8, with filiform filaments shorter than the petals: style as long as the filaments; stigma with 4 divergent lobes: capsule becoming twice as long as the pedicels, 3^{cm}, purple, narrowed at each end, but with the apex truncate: coma on seeds dingy white.

UMBELLIFERAE.

116. HERACLEUM LANATUM Michx. Fl. 1: 166. 1803.—This is easily distinguished from all other members of this family by

the large ternate leaves with broad round-cordate cut-toothed leaflets: umbels large, and petals of the outer flowers generally dilated and 2-cleft.

The leaf-stalks and stems of this plant are used as food by the aborigines. Along the streams and near springs.

Type range: "in Canada."

CORNACEAE.

117. CORNUS SUECICA L. Sp. Pl. 118. 1753.—Distinguished from its near relative, *C. canadensis* L., by the 2-forked stem at the leaf axils of the first flowers.

Under the willows.

Type range: "in Suecia, Norvegica, Russia."

ERICACEAE.

118. ARCTOSTAPHYLOS ALPINA Spreng. Syst. **2**: 287. *Arbutus alpina* L. Sp. Pl. 395. 1753.—Stems forming mats with woody branches, creeping: leaves thin, deciduous, obovate-elliptical, acute, tapering at base to a margined petiole, ciliate when young, about half as long as the blade; margin serrate; surface smooth, veiny, turning reddish-purple: fruit a red, juicy berry, containing 5 seeds.

The berries which were collected and preserved in formalin may not be ripe. According to the descriptions they are black when ripe.

Type range: "in Alpibus Lapponiae, Helvetiae, Sibiriae."

119. ANDROMEDA POLIFOLIA L. Sp. Pl. 393, 1753; Fl. Lapp. *pl. 1. fig. 3.*—This pretty little plant has globular urn-shaped, rose-colored flowers in few-flowered terminal umbels: the narrow leaves are so strongly revolute as often to show only the midrib, sometimes not even that; lower leaf surface pale, upper bright green.

Type locality: "in defertis subhumidis muscosis and paludosis etiam in Alpibus immer per totam Sueciam, mixta vaccinio crescit."

120. CASSIOPE TETRAGONA Don. Edinburg. N. Phil. Jour. **17**: 158. 1834. *Andromeda tetragona* L. Sp. Pl. 393. 1753.—Leaves imbricated in four ranks, each with a groove down the middle: the pretty white bells are at the summit of the stems and hang from the top of erect thread-like peduncles.

Type locality: "in Alpibus Lapponicis."

121. LEDUM PALUSTRIS L. Sp. Pl. 391. 1753.—Shrub with leaves linear, revolute, clothed with brown wool on the lower surface, marked with quadrangular veining on the upper: flowers white, in corymbs terminating the branches.

Type range: "in Europae septentrionalis paludibus uliginosis."

122. LOISLEURIA PROCUMBENS Desv. Journ. Bot. 1: 35. 1808. *Azalea procumbens* L. Sp. Pl. 151. 1753; Fl. Lapp. *pl. 6. fig. 2.*—A pretty little prostrate suffrutescent plant, with small crimson open-campanulate flowers in umbels terminating the stems.

Type range: "in Alpibus Europae."

123. RHODODENDRON KAMTCHATICUM Pall. Fl. Ross. 1: 48. *pl. 33.*—One of the most beautiful of arctic plants: leaves obovate-spatulate, veiny, bristly-ciliate: flowers rich crimson, with the calyx persistent and the divisions of the corolla almost an inch long.

Type locality: "Kamtchatka."

124. RHODODENDRON LAPPONICUM Wahl. Fl. Suec. 249. 1824. *Azalea Lapponica* L. Sp. Pl. 151. 1753.—A low much branched prostrate shrub about 8^{cm} high, with rough brownish bark, the outer part splitting irregularly into small plates: leaves clustered at the ends of the branches, oblong to elliptical or even ovate, $3–10^{mm}$ long, about half as wide, with entire revolute margins, mucronate apex, subcuneate base, midrib sulcate on the upper surface and prominent on the lower, surface minutely pitted, the pits covered with a brown scale, denser on the lower surface: flowers on peduncles a little longer than the petioles, 2 or 3 at the ends of the branches, apparently without bracts: calyx of 4 very short round divisions about 1^{mm} long and wide, green or purplish, ciliate, lepidote with greenish scales: corolla purple, rotate-campanulate, of 4 oblong-orbicular lobes twice as long as the tube, 3 larger than the fourth, wavy-margined, hairy in the throat, glabrous otherwise: stamens 7 or 8: style purple, twice geniculate; stigma capitate; ovary narrowly ovoid, lepidote.

There was but one specimen of this collected, and the peculiarity of the

four divisions of the perianth may be an individual characteristic. In other respects it resembles the figure in Bot. Mag. *pl. 3106*.

Type range: "in Alpibus Lapponiae."

125. VACCINIUM ULIGINOSUM L. Sp. Pl. 350. 1753.—This arctic huckleberry has solitary or clustered, pendent, globular urn-shaped flowers: leaves deciduous, pale and veiny on the lower surface, smooth or puberulent on both sides, with revolute margin, and obtuse, retuse, or sometimes mucronate apex: berry said to be blue-black, covered with a bloom when ripe.

Type range: "in Sueciae borealibus and alpinis; uliginosis."

DIAPENSIACEAE.

126. DIAPENSIA LAPPONICA L. Sp. Pl. 141. 1753; Fl. Lapp *pl. 1. fig. 1.*—Suggests a plant belonging to the Ericaceae, with its mat of shining evergreen leaves: stamens inserted in the sinus of the lobes of the corolla, and anthers obliquely dehiscent: capsule loculicidally 3-valved.

The pretty white flowers suggest those of *Moneses uniflora* Gray.

Type locality: "in Alpibus Lapponicis."

PRIMULACEAE.

127. ANDROSACE CHAMAEJASME Willd. Sp. Pl. 1: 799. 1797.—This pretty little primrose differs from the common form of this variable species. The corolla is white with a yellow eye, later turning purplish with the eye purple. The leaves are small and clustered at base in a rosulate bunch. The flowers are small in a capitate umbel, terminating a slender scape about 3^{cm} high.

Type locality: "in Austriae alpibus."

128. DODECATHEON FRIGIDUM Ch. and Schl. Linnaea 1: 223. 1826.—Scape from 5^{cm} to 3^{dm} high (in fruit): roots fleshy-fibrous, from an oblique rootstock: leaves spatulate, oval or almost orbicular to ovate, glabrous; margin sinuate: umbels 2–3-flowered, with diavaricate pedicels glandular-puberulent with purple glands (this pubescence also found on the calyx and the upper part of the scape): involucre of short, subulate bracts: flowers nodding, violet: divisions of calyx deltoid, 2^{mm} long:

lobes of corolla ligulate, 15^{mm} long: anthers on very short filaments, connate: capsule about twice as long as the calyx, the top falling off when the seeds are ripe.

Type locality: "frigidissima loca Sinus St. Laurentii, a nive defluente irrigata."

129. PRIMULA MISTASSINICA Michx. Fl. Am. Bor. **1**: 124. 1803.—Roots fibrous, white: leaves clustered at the base of the scape, elliptical, dentate in the upper part, cuneate and entire in the lower; petioles from almost none to twice the length of the blade, sheathing at base: scape about 1^{dm} high, slender: umbel 2–many-flowered; involucre of narrow linear-acuminate bracts; pedicels varying in length from $2–10^{mm}$: calyx of narrowly deltoid minutely puberulent divisions about equaling the tube of the corolla: corolla white with yellow tube, the limb consisting of five 2-lobed divisions.

Type locality: "ad lacus Mistassins Canadam inter et fretum Hudsonis."

130. PRIMULA NIVALIS Pall. It. **3**: 320, 444; App. 723. *pl. G. fig. 2;* Ch. & Schl. Linnaea **1**: 215.—Roots fleshy-fibrous: leaves and scape from a stout caudex clothed with broad ovate scarious scales: leaves broadly lanceolate, narrowed to the petiole, which is somewhat shorter than the blade; margins from entire to sinuate-dentate: scape slender, 2–3 times as long as the leaves: umbel few-flowered; involucre, upper part of scape, pedicels, and calyx more or less farinose; bracts of involucre linear-acuminate: divisions of the calyx longer than the tube, black-purple, edged with white-farinose margins, about half as long as the tube of the corolla: corolla crimson, salverform, with elliptical divisions shorter than the tube: flowers nodding at first, later becoming erect.

There are some fragmentary specimens with many-flowered umbels and shorter and stouter scapes and pedicels. This species appears to vary extremely. Chamisso and Schlechtendal describe the various forms which they found in different localities. Two flowering stalks which are very young, having the flowers declined on one side in a farinose umbel, are probably specimens of *Primula eximia* Greene, Pittonia **3**: 251.

131. TRIENTALIS EUROPAEA ARCTICA Ledeb. Fl. Ross. **3**: 25.

1846–1851. *T. arctica* Fisch. Hook. Fl. Bor.-Am. **2**: 121. 1840.—Stems very slender, filiform, about 7^{cm} high, with 1 or 2 very small leaves (not more than 5^{mm} long) below the whorl: whorled leaves oblanceolate to obovate, entire, thin, varying in size from $5–15^{mm}$: flower solitary on a filiform stem about as long as the rest of the plant: sepals 6, narrowly linear-acuminate, reddish: petals white, narrowly obovate or elliptical, mucronate at apex, 5^{mm} long, almost twice as long as the sepals.

In regard to *T. Europaea* in Fl. Lapp., Linnaeus says that the divisions of the corolla are acute when the plant grows in dry places, obtuse in wet places. This differs from *T. arctica*, according to the description, in having petals mucronate instead of obtuse.

Type range: "Western shore and islands, from Sandy bay, in Clarence straits (Tolmie), to Unalashka, Langsdorff, Chamisso."

PLUMBAGINACEAE.

132. ARMERIA VULGARIS Willd. Enum. 133. *Statice Armeria* L. Sp. Pl. 274. 1753.—Root vertical, slender, fusiform: caudex densely clothed below with the brown sheathing dilated petioles of former leaves; above with the rosulate cluster of green leaves: these linear, obtuse or acute, about as broad as the scape and 2–4 times shorter, ciliate on the margins, otherwise entire: scapes glabrous, $1–2^{dm}$ high, capped by the head of flowers; lowest bracts sheathing the stem, connate, laciniate, brown; outer ones brown tinged with pink, orbicular or broadly ovate, glabrous, scarious; inner ones among the flowers similar but thinner, equaling the flowers: these on short slender pedicels: calyx with the border 5-toothed, with erosely margined submuticous teeth, ribbed, hairy on the ribs below, white suffused with pink; tube turbinate, with 10 ribs densely clothed with upwardly-appressed hairs.

This is one of the numerous forms of this variable species, some of which have been described as distinct.

[*To be concluded.*]

AN EMBRYOLOGICAL STUDY OF LIMNOCHARIS EMARGINATA.

JOHN GALENTINE HALL.

(WITH PLATE IX)

Limnocharis emarginata is of South American origin. The plants from which material was taken for study are growing in a large tank in the aquatic house at North Easton, under conditions that appear to be normal, and are certainly favorable for propagation, as is shown by the maturing of abundant seed from the self-pollinated flowers, and the large number of seedlings that spring up spontaneously in the tank.

The discrepancies in the comparative embryology of the group to which Limnocharis belongs, as represented by the work of Marshall Ward, Schaffner, Campbell, and others, seemed to justify careful examination of the present material. I shall give no account of the general morphology, as Buchenau has described the development of the flower and of the tissue of the growing point.

The ovules in their general development follow very closely the development of the ovules of *Butomus umbellatus* as described by Marshall Ward. They arise as emergences from the walls of the carpels without definite placental arrangement. The subsequent development is of the usual angiospermous type, except the history of the embryo sac. Each integument is composed of two layers of cells, the inner being a trifle longer than the outer, and forming a considerable mass of tissue at the apex of the ovule around the micropyle, as is the case in Naias and Zannichellia. From the outer coat, soon after fertilization, certain cells begin to develop into short hairs that give the seed a rough appearance. Long before the seed coats begin to form, the growth of the ovule is more rapid on one side (*fig. 3*), and anatropy is already marked when the rudiments of the coats make their appearance (*fig. 4*).

Very early it is possible to distinguish the single hypodermal cell that forms the archesporium (*fig. 2*). It is somewhat larger than the surrounding cells, and the nucleus is considerably larger than those of the adjacent cells. There is a tapetum cut off by the archesporial cell, such as is described by Campbell for Naias and Zannichellia. In Limnocharis, however, the tapetal cell is without a wall, and it is pushed towards the apex of the sac (*fig. 4*), where it disappears in the later stages of development. The large cell left after the formation of the tapetum becomes the embryo sac without further division. About the time the first division takes place in the embryo sac the epidermal cell that overlies it divides by a periclinal wall, forming a false tapetal cell (*fig. 4*). In Butomus, according to Marshall Ward, there are two cells cut off in succession from the apex of the archesporial cells, and sometimes the first one divides once longitudinally. These three cells have very deliquescent walls, and soon disappear.

The history of the nuclear changes in the embryo sac differs considerably from the ordinary in the last stages. After the first division of the megaspore nucleus, the two daughter nuclei migrate to each end of the sac. The one that goes to the micropylar end passes through the usual divisions to form the egg apparatus and upper polar nucleus; while the one that goes to the antipodal end remains undivided (*figs. 5–8*). In Butomus, Marshall Ward says that sometimes only two nuclei are formed at the antipodal end of the sac, and that one of these fuses with the upper polar, leaving only one antipodal. The antipodal is not cut off by a wall from the sac in Limnocharis, Butomus, or Alisma, while in Sagittaria, Naias, and Zannichellia cell walls are formed around each of the antipodal nuclei.

The secondary nucleus at the micropylar end of the sac divides transversely (*fig. 5*), and then each of the resulting nuclei divides longitudinally (*figs. 6–7*), but not always simultaneously, making the usual four at that end of the sac. The lower one of the two nuclei, by division, makes the egg and upper polar; while the other forms the two synergids.

At this time, the upper polar nucleus (*fig. 8*) begins a migration toward the antipodal end of the sac, at the same time increasing somewhat in size, so that it has very much the appearance of an endosperm nucleus. This migration continues until the nucleus reaches the region of the antipodal nucleus (*fig. 9*), though no fusion takes place, for the latter can be seen in all but the very latest stages of the embryo sac and embryo. The upper polar nucleus, when it has approached the antipodal end of the sac, divides transversely (*fig. 10*). The lower daughter nucleus remains in the position of its formation, being cut off by a wall across the sac (*figs. 11–12*), and forming a large cell that does not divide further, but finally disappears through the encroachment of the endosperm. In *Butomus umbellatus*, Marshall Ward says that the two polars approach the middle of the sac, where they fuse, forming a definitive nucleus, and leaving only one antipodal nucleus. In Sagittaria, Schaffner shows a similar division of a large nucleus, and formation of a wall across the sac, near the antipodal end, which he says takes place after the fusion of the polar nuclei; and he states that frequently the nucleus of the cell cut off toward the lower end of the sac divides to form two or three, when the embryo is in about an eight-celled stage. Campbell describes a similar large nucleus in both Naias and Zannichellia, but does not state definitely what is its origin. He makes no mention of any wall cutting it off from the rest of the endosperm, but suggests that it may be the lower polar nucleus. Such cannot possibly be the origin of the one in Limnocharis, because there is no lower polar formed. Campbell also says that the nucleus resembles the suspensor nucleus in Naias and Zannichellia, which is the case in Limnocharis, except that the nucleus stains more readily than the suspensor nucleus.

The upper daughter nucleus travels back toward the egg apparatus (*figs. 11, 12*), and by its further division forms the endosperm. At an early stage the endosperm consists of only a single layer of granular protoplasm lining the sac, in which are embedded free nuclei, as in Naias and Zannichellia; but later, in Limnocharis, walls are formed, although they are not easily

distinguishable. Schaffner says that the endosperm is not abundant in Alisma; but as he does not follow the development of the embryo far, might it not be, as in the present case, that it finally completely fills the sac?

Before the polar nucleus, which forms the endosperm, has gone through the first division, fertilization has taken place; for at this time the egg nucleus has divided so that there are now two nuclei in the young embryo (*fig. 12*), and the remains of the pollen tube can be seen in many cases. Actual fusion of sperm nucleus and egg was not observed. It is evident that fertilization takes place very soon after pollination, from the fact that material killed within eighteen hours after pollination showed the embryo in a two-celled stage, with the disintegrating remains of the pollen tube near by. Fertilization probably occurs in the first night after pollination.

For the study of the development of the embryo, most of the ovules, which are U-shaped, were taken from the ovary and embedded in watch glasses for sectioning.

The first division of the egg after fertilization is transverse, and divides the cell into suspensor and embryo-cell (*fig. 13*). The original suspensor cell increases very much in size (*figs. 14–16*), has an exceptionally large nucleus, and never divides save in case of polyembryony. In this case it divides and subdivides to form an embryogenic mass, from which grow out as buds several young embryos (*figs. 17 a, b, c*), somewhat as in *Erythronium americanum* and *Tulipa Gesneri*. Whether these all mature or not I cannot say, for polyembryony is not very frequent, and I was unable to find any older stages than those shown in *figs. 17 a, b, c*, although I observed a number of younger stages.

The suspensor in the older embryo is not wholly composed of the original suspensor cell, but appropriates some of the cells that come from the first terminal segment until it contains sometimes four and even five cells (*figs. 28, 29*). The second division is always transverse (*fig. 14*), while the third division takes place in three different directions, transversely, vertically, and

obliquely (*figs. 15, 18, 19*). In cases it is vertical or oblique, the growing point and the cotyledon both arise from terminal segments, agreeing with Zannichellia in this particular, but differing from Naias. After having examined a very large amount of material, I have come to the conclusion that there is no regular order of division in the active nuclei of the young embryo, at least after the first two walls are formed (*figs. 15–27*), and have thought that where descriptions do not agree it should perhaps be ascribed to the variation of development rather than to any incorrect statements or observations of the earlier writers. In *figs. 24* and *25* there are four transverse walls formed; in *fig. 25* there is no sign of division of the terminal cell; while in *fig. 24* the terminal cell is in process of division. In *fig. 16* there are three transverse walls, the terminal cell being divided vertically, while the cell next to the suspensor is in process of division.

In the further development it was impossible to follow the order of the divisions, and in the older stages of the embryo it seemed that the growing point was of lateral origin always (*figs. 22, 28, 29, 30*). The mature embryo is U-shaped (*fig. 31*), and the growing point is in the basal quarter of the embryo, apparently wholly surrounded by the epidermal layer.

This work was done at the Ames Botanical Laboratory, North Easton, Mass., under the direction of Oakes Ames.

NORTH CAMBRIDGE, MASS.

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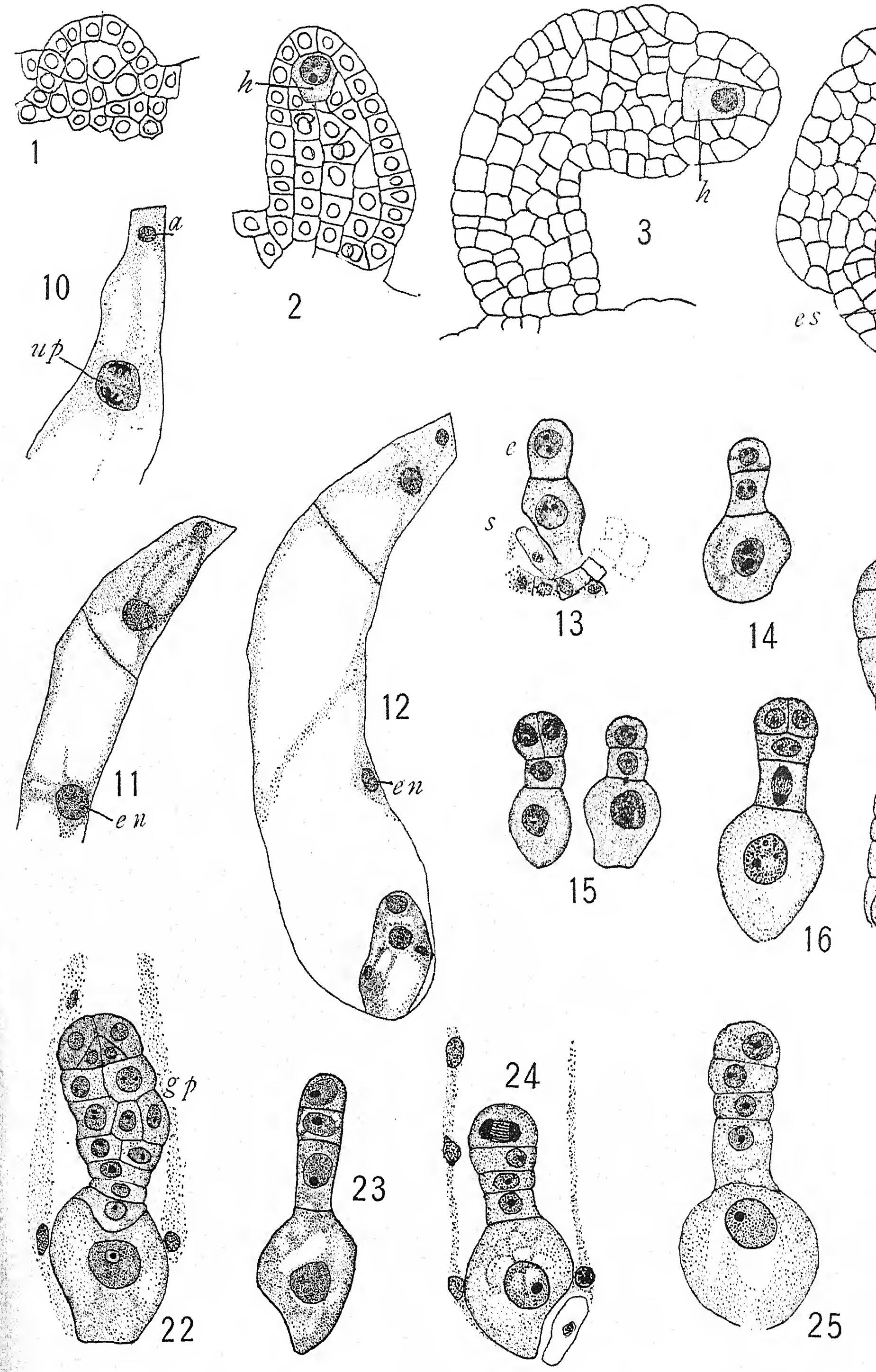
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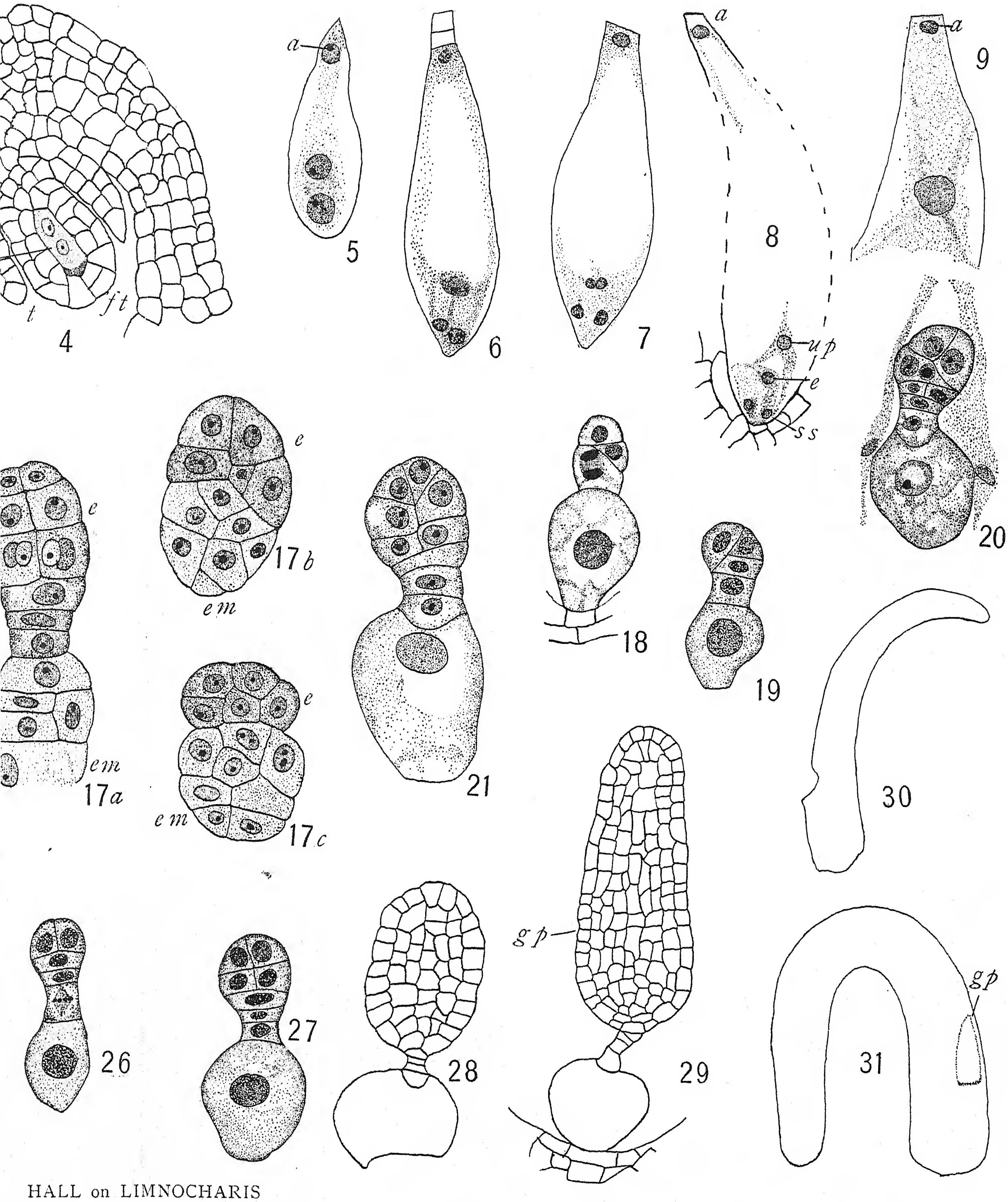

HALL on LIMNOCHARIS

EXPLANATION OF PLATE IX.

FIG. 1 Very young ovule.

FIGS. 2, 3. Older stages of ovule showing archesporium (*h*).

FIG. 4. Ovule; *es*, embryo-sac; *ft*, false tapetal cell; *t*, tapetum.

FIGS. 5–7. Different stages of embryo-sac; *a*, antipodal.

FIG. 8. Mature embryo-sac; *a*, antipodal; *up*, upper polar; *e*, egg cell; *ss*, synergids.

FIGS. 9, 10. Lower end of embryo-sac showing antipodal (*a*) and upper polar (*up*) in process of division.

FIGS. 11, 12. Embryo-sac showing peculiar cell cut off from sac at antipodal end, and endosperm nucleus (*en*).

FIG. 13. Young embryo; *e*, "embryo-cell;" *s*, suspensor.

FIGS. 14–16. Succeeding stages of young embryo; *fig. 15*, two sections of same embryo.

FIGS. 17 *a*, *b*, *c*. Three sections of one embryogenic mass (*em*) with embryo-buds (*e*).

FIGS. 18–30. Stages of embryo; *gp*, growing point in *figs. 22–29*.

FIG. 31. Mature embryo; *gp*, growing point.

GENERIC NOMENCLATURE.

C. L. SHEAR.

THE application and limitation of generic names is a subject which has lately received considerable attention, not only from botanists, but from systematic biologists in general. Efforts to secure at least a degree of uniformity and stability in the use of scientific names have become more general in recent years, and quite naturally have been directed chiefly to specific designations. To one who will give the matter careful consideration, however, it must appear clear that the stability of the generic name is of primary importance, and must be secured before we can hope for stability of the binomial. I am aware that questions of nomenclature are considered beneath the notice of some botanists, especially some of those whose fields of labor do not bring them into very close contact with taxonomy; but there is no student of plant life in any of its multidudinous phases but must have occasion at some time to use plant names, and hence should be interested to some degree, at least, in any sincere effort to secure stability and uniformity in nomenclature.

Personally, I have long tried to avoid and evade the subject, believing that too great importance was attributed to it; and I am still far from regarding it as an equivalent for biological research; but having undertaken some taxonomic work, I found myself confronted by certain questions that must be decided.

The present discussion of this subject relates especially to the fungi, as I have made no special investigation of the conditions prevailing in any other group except the grasses.

To one who has never had occasion to trace the origin and history of a generic name through literature, it may appear that there is very little diversity in the application of such names, but a careful comparison of the use and interpretation of generic names by different authors soon reveals the fact that each

followed his favorite author or his individual preference or conception, which is not always based upon any serious consideration of the consequences, and leads naturally to little uniformity. An abundance of instances verifying this statement might be cited, but we shall take space to refer to only a few. Let us glance first at one or two of the older genera. Take for example the genus *Lycoperdon*. So far as we know, the name was first used by Tournefort,[1] who gave brief descriptions of twenty-eight species, including a considerable variety of Gasteromycetes. His plate illustrating the genus represents four species, two of which belong to the present genus as interpreted by DeToni.[2] The two others belong to distinct genera. It would require too much space to trace the entire history of the genus as interpreted by different authors down to the present time. Michelius[3] and most other authors until Linnæus used the name in much the same sense as Tournefort. Linnæus,[4] in *Genera Plantarum*, greatly enlarged the scope of the genus, and included many things previously separated by other authors. Interpreting his idea of the genus by the species referred to it in *Species Plantarum*, we have a very heterogeneous collection. Of the nine species described by him, but one is found in the genus as interpreted in Saccardo,[2] and even that one is not included by some recent authors. Myxomycetes, Ascomycetes, and Uredineæ are represented among Linnæus' species. Postlinnæan authors vary in their interpretation of the genus, and also as to whom it should be credited. The conceptions of Tournefort and Michelius, as shown in their illustrations of species, have apparently exercised the greatest influence, and have led to the present more or less general interpretation of the genus. The present application of the name is the natural outcome of following what might be called the lines of least resistance, which has lately been designated the "residue method," but was at first really no conscious method at all.

[1] TOURNEFORT, Ins. Rei Herb. 1:563. *pl. 331*. 1700.

[2] DETONI, Saccardo Syll. Fung. 7:106. 1888.

[3] MICHELIUS, Nov. Pl. Gen. 217. 1729. [4] LINNÆUS, Gen. Pl. 328. 1737.

The genus *Agaricus* affords another interesting example established by Tournefort,[5] who referred to it chiefly species of *Polyporus* in the sense of Saccardo, and figured as representing his idea of the genus, *Polyporus fomentarius* (L.) Fr. It was later taken up by Dillenius[6] and also Linnæus,[7] who referred to it chiefly lamellate forms. Since, the genus has been divided and subdivided until the name has become entirely displaced or relegated to a few imperfectly described species which could not be definitely referred. Karsten, Patouillard, and Saccardo[8] have applied the name to a group of species, including the common mushroom, *Agaricus campestris* L. But why should it be retained for this group rather than for any of the dozen or more groups to which it had equal claim? If any reason were given, it would probably be that this was the best known group, containing the species which has long been grown and collected for food.

The history of the genus *Sphaeria* Haller[9] is also very interesting, and shows how names are entirely displaced, or relegated to groups of insufficiently described species or indeterminate odds and ends of old authors.

Lest it should be inferred that such *laisser faire* proceedings are characteristic of the older authors only, we may call attention to one or two modern instances. Take the genus *Valsaria* Ces. & De Not.,[10] for example. Four species were positively referred to the genus and five others doubtfully by these authors. Later De Notaris[11] described and referred to the genus two

[5] TOURNEFORT, Ins. Rei Herb. 1: 562. *pl. 330.* 1700.

[6] DILLENIUS, Nov. Gen. 75. 1719.

[7] LINNÆUS, Gen. Pl. 327. 1737.—Sp. Pl. 2: 1171. 1753.

[8] SACCARDO, Syll. Fung. 5: 993. 1887.

[9] HALLER, Hist. Stirp. Helv. 3: 120. 1768.

[10] CESATI and DE NOTARIS, Schem. Sfer. Ital. Asc. in Comm. Crit. Soc. Ital. 1: 205. 1863.

[11] DE NOTARIS, G., Sfer. Ital. 57. 1863. This was published nearly a year after the last publication cited. The preface to fasc. 2, in which the above citation occurs, is dated December 1863, while the Schem. Sfer. Ital. is referred to in the preface to fasc. 1 which is dated March 1863, indicating that it appeared earlier in the year.

more species, the last of which was *V. tiliae.* Now note the treatment of this genus by two recent authors, Saccardo[12] and and Lindau.[13] Saccardo included most of the species originally referred to the genus by its authors and added a considerable number of others. Lindau cites De Notaris as the sole author of the genus, and restricts it to two species, only one of which is mentioned, *V. tiliae*, which was referred to the genus by De Notaris (*l. c.*), but was not included in it by the original authors, and was soon after taken as the type of the genus *Hercospora* by Tulasne.[14] It is scarcely worth while to multiply examples; any one who cares to look into the matter will find them without difficulty and in endless variety. For some cases of a similar sort among genera of ferns consult Underwood.[15]

It has been urged that instances of this kind are exceptional, but any one who takes the trouble to investigate the matter will find that they are exasperatingly frequent among the fungi, and I am told by those who have investigated the matter that the case is practically the same in other groups. The instances in which old generic names have been entirely displaced or transferred to different plants from those originally included are most numerous, and arise generally from the lack of uniformity in the subdivision or segregation of large or composite genera. A genus is divided into several subgenera, these are in turn raised to generic rank, the original name being entirely displaced or left with an undeterminable or miscellaneous residue, which the original author never included in it or at least did not regard as typical.

The first attempt, so far as we know, to formulate any rule for guidance in the segregation of large or composite genera was that of the Paris code, article 54 of which reads as follows:

Lorsqu'un genre est divisé en deux ou plusieurs, le nom doit être conservé et il est donné à l'une des divisions principales. Si le genre contenait

[12] SACCARDO, Syll. Fung. 1: 741. 1882.

[13] LINDAU, Eng. and Prantl Pflanzenfamilien I. 1: 470. 1897.

[14] TULASNE, L. R. & C., Sel. Fung. Carp. 2: 154. S 1863.

[15] UNDERWOOD, L. M., Rev. Gen. Ferns, Mem. Torr. Bot. Club 6: 251 and 279. D 1899.

une section ou autre division qui, d'après son nom ou ses espèces, était le type ou l'origine du groupe, le nom est réservé pour cette partie. S'il n'existe pas de section ou subdivision pareille, mais qu'une des fractions détachées soit beaucoup plus nombreuse en espèces que les autres, c'est à elle que le nom doit être réservé.

This rule is so indefinite, and requires so much in the way of personal interpretation and judgment, that it has not produced uniform results in the hands of those who have sincerely attempted to use it as a guide. Kunze,[16] recognizing the impossibility of securing uniformity under this rule, proposed a modification of it which should make it more definite. As no particular period in the history of a genus is designated to be taken as a basis for applying the Paris code rule, Kunze very aptly remarks that it leaves us "über die höchst wichtige Frage im Unklaren." He emended this article so that it should require the generic name to be applied to the majority of the species included in the genus at the time of its valid establishment.

This has been designated the "species majority" method. While Kunze's amendment is a decided improvement, it is still incapable of giving us stability and uniformity in the application of generic names.

In the first place, it does not provide for the cases in which but two species were originally referred to a genus, either of which may be equally entitled to retain the name when the genus is divided. The fatal difficulty, however, is that the selection of the species which are to be considered as belonging to the genus must be based upon the reviser's conception of the genus, or upon the conception of the author that he may choose to follow, and it is quite unnecessary to call attention to the great diversity of generic concepts which has obtained, and still obtains, among botanists.

The Rochester rules make no direct provision for the treatment of genera, but refer all questions not particularly provided for to the Paris code.

The so-called "residue method" is the one which has been most generally accepted by adherents to the Rochester rules. I have

[16] KUNZE, O., Rev. Gen. Pl. 1: XCII. 1891.

long sought in vain for an authoritative statement of this method, but have until very recently been unable to learn of any attempt to formulate it. Thanks to Dr. Underwood,[17] who has bravely attacked the problem of generic types, we have the following statement: "The method of 'residues' works on the principle that the last species remaining in the genus from those originally named by its author when the genus was founded shall constitute the type of the genus and shall hold the generic name."

The fatal objection to this and to the other methods is that, being capable of and depending upon the varied interpretation by different authors, it cannot lead to uniformity. Besides this there are many instances in which several genera, each containing a number of species, were established at nearly the same time, which make it impossible to adjust generic limitations by means of this method.

The fundamental failing of all these plans is that the generic name remains movable, and is capable of being shifted about from one end of a series of species to the other, these species frequently representing different genera and sometimes families. As Dr. Jordan[18] aptly puts it: "These methods have lacked the one important element of inevitableness." The first and fundamental step to be taken is to fix generic names at one point by means of an assigned type, in case none was originally designated by the author. This method has already been proposed by Cook,[19] and also by Underwood, *l. c.* We can scarcely expect to secure entire uniformity in generic limitations, as various authors naturally differ in regard to the scope of genera, but if some practicable method can be devised for anchoring generic names at fixed points, we shall always know where to find at least the nucleus of the genus, however much it may have been enlarged or contracted since its origin.

The type method in regard to species has gained general recognition so far as present practice is concerned, though we regret to say that one still occasionally sees new species

[17] *Op. cit.*, 252. [18] JORDAN, D. S., Science N. S. **13**: 499. 29 Mr 1901.

[19] COOK, O. F., Science N. S. **8**: 186–190. 12 Ag 1898; 513–516. 14 O 1898.

described without the citation of a type specimen. The type method is equally or even more necessary and applicable in the case of genera; but admitting the advisability and possibility of such a method the details still remain to be arranged. Cook, *l. c.*, has discussed the question in general; Underwood, *l. c.*, has formulated a set of rules for fixing types and applied them to the genera of ferns; Jordan, *l. c.*, has also recently given us his views regarding the matter.

It seems very desirable and important that this matter should be thoroughly investigated and discussed before any fixed plan is adopted for putting the method into practice.

The essential features of any rule should be simplicity, clearness, and comprehensiveness. Rules which require or give opportunity for personal choice or interpretation cannot lead to uniform results. Provision should be made for all classes of cases involved, and this necessitates a thorough knowledge of all taxonomic literature. To one not familiar with the great diversity of practice among the botanists of the eighteenth century, the brief rule, "the first-named species of each genus shall be regarded as its type," would seem to fulfill all the requirements mentioned above. But would "the first-named species" apply to both polynomial and binomial species? And what would become of a genus whose author never referred to it a binomial species, but cited good figures of polynomial species? Rules will also have to be modified according to the time taken as a starting point for genera. The present starting point of the Rochester rules, 1753, seems very illogical and unsatisfactory for genera, and we believe will eventually be abandoned.

Let us examine briefly the various plans already proposed for the fixing of types. Mr. Cook, who was one of the first to propose the type method, has published no formal statement of rules, but says that genera should be fixed "by confining the application of a generic name to the genus in which its assigned type or first binomial species is included." Whatever the starting point might be this would require that genera established by polynomialists should be interpreted by their first successor using

their generic names with binomial species. Thus, in the case of Haller,[9] this plan would lead to the application of his generic names to different groups from those to which they would be applied by taking his first species as a type. It may be the intention, however, to disregard the genera of polynomialists entirely, as well as all those based upon descriptions not accompanied by direct citation of binomial species.

Dr. Underwood, *l. c.*, has formulated a series of rules and made a practical application of them. He adopts 1753 as his starting point, and designates what are to be regarded as valid genera as follows: "(*a*) based on one or more previously described species which are referred to with sufficient directness to be recognizable, or (*b*) based on some species which is described for the first time at the establishment of the genus itself."

For the selection of types the following rule is given: "For each genus established, the first named species will be regarded as the type." Two exceptions to this are made. One is that Linnæan genera must be traced to their types wherever they originated, and "in case the original generic name was used in another sense than that which it was adopted by Linnæus, the the type of the genus in the Linnæan sense must be determined wherever it was first used." The other exception covers cases in which "a definite statement of the type" is made by the author of the genus.

The application of these rules leads to entirely different results from those which would be reached by following Mr. Cook's plan. The difference is due in great part to the manner in which Dr. Underwood determines the types of Linnæan genera. Adopting 1753 as a starting point, and then selecting types for genera from Linnæus's earlier work, appears rather illogical. If types are to be taken from works earlier than 1753, why not date them accordingly? There also seems to be need of more definite provisions for determining the types of such genera as those of Adanson,[20] which are accepted by Underwood but do not appear to be interpreted according to any rigid rule.

[20] ADANSON, Fam. Pl. 1763.

We fear that other authors, attempting to follow these rules in an entirely unprejudiced manner, would not arrive at the same results. This, however, is distinctly an effort in the right direction, and due credit should be given for it.

Dr. Jordan, *l. c.*, in connection with his excellent review of the subject, suggests provisional rules for applying the type method. His rule 2, which covers the principal points at issue, is as follows: "If no type is designated by the author, either explicitly or by clear implication, then the first species referred to the genus or the species standing first on the page shall be considered as its type. A generic name should have no standing if resting on definition alone, nor until associated with some definite species."

With the exception of the expression "or by clear implication," this rule comes nearest to meeting the requirements for simplicity, clearness, and comprehensiveness. The phrase referred to, however, as well as several exceptions which the author adds, seems to present very undesirable opportunities for the exercise of personal opinion and choice, which are so fatal to uniformity.

It is not our intention to attempt to offer a set of rules which shall be perfect, and meet all the requirements of the case, but simply to avow our belief in the desirability and practicability of the type method, and to point out some of the matters which should be given careful consideration and investigation before any rules are generally adopted.

Of primary importance in this connection is the selection of a starting point for genera which may meet with general acceptance.

Definite provision should also be made for the treatment of genera having no binomial species referred to them at the time of their original description. It seems scarcely just to discard a generic name because it happened to originate with a polynomialist (*e. g.*, Haller, to cite a case after 1753), or in cases like that of Adanson, *l. c.*, when definite figures of identifiable species are cited instead of specific names,

It is to be hoped that careful consideration and study will be given to all the different phases of this subject, and that it will be thoroughly discussed from all points of view in order that any authoritative action in the way of formulating rules which may be taken may fully meet the requirements of the case and not prove premature.

WASHINGTON, D. C.

BRIEFER ARTICLES.

NOTES ON SOME AMERICAN TREES.

Fraxinus catawbiensis, n. sp.— A large tree 20–35^{m} in height, with a cylindrical or gently tapering trunk often 7^{dm} in diameter, and straight ascending branches forming an oval crown; the gray-brown bark on the trunk deeply furrowed, the ridges flat-topped and frequently anastomosing, that of the branches brown and smoother. Twigs stout, somewhat flattened and quadrangular between the nodes, about 5^{mm} thick, the first season dark brown and velvety with a close pubescence, becoming gray-brown and glabrate the second year, and marked with a few small pale gray lenticels; the winter-buds dark brown, scurfy, short and blunt; leaf-scars large, lunate or semi-orbicular. The leaves (2–3^{dm} long) borne on stout spreading velvety-pubescent petioles, consist of 7–9 drooping leaflets which are oblong-ovate, 7–10^{cm} long, 4–5^{cm} wide, rounded or subcordate at base, taper-pointed at the apex, usually entire, thick and firm in texture, dark green and glabrous on the upper surface, white and glaucous beneath, with brown pubescence on the midrib and primary veins; petiole short, velvety-pubescent. The flowers appear in the vicinity of Raleigh, N. C., from the first to the middle of April. The fruit, which is borne in loose pendent clusters, is about 3^{cm} long, the cylindrical brown body about 1^{cm} long and 3^{mm} thick, the narrow ligulate wing about 4^{mm} wide; ripens and falls in October; calyx glabrous, scarcely 1^{mm} long, sharply toothed.

The Catawba ash frequents the alluvial river banks of the Piedmont region of the Carolinas, growing with the black birch, red maple, sweet gum, the white and green ashes, and the bitternut hickory; and is not uncommon in the vicinity of Raleigh, N. C., at an altitude of 110^{m}, and Marion, N. C., along the Catawba river and its tributaries, at an altitude of 400^{m}. It is closely related to the white ash, from which it is separated by the darker foliage, glaucous white beneath, the soft pubescence of the twigs and petiole, and the darker winter-buds; while from *Fraxinus biltmoreana* and *F. profunda*, which it closely resembles in foliage and pubescence, it is separated by the shorter and smaller fruit and smaller calyx.

TILIA HETEROPHYLLA Vent.—The northern limit of this species is usually given in the mountains of Pennsylvania; this being the limit

assigned by Professor Sargent in his *Sylva*, and in the sixth edition of Gray's *Manual*, and in Britton and Brown's *Flora of the Northern States*. In 1892 the writer collected specimens of a linden from Fall creek, near Ithaca, N. Y., and in 1897 similar specimens from near Watkins glen, New York, which are undoubtedly from the white linden, having its close silvery pubescence on the lower surface of the leaves, and the subglobose fruit covered with short cinereous tomentum, characters common to no other species of the eastern United States.

Tilia eburnea, n. sp.—A tree $10–22^{m}$ in height, with dark gray-brown furrowed bark on the trunk, and smoother silver-gray bark on the branches. Twigs stout, $5–6^{mm}$ thick, soft, glabrous, occasionally sparingly glaucous, those of the season bright green, brown or red-brown, becoming gray the second year; buds large, ovate, glabrous, sometimes glaucous. The leaves are ovate or round-ovate, $8–14^{cm}$ long, $7–12^{cm}$ wide, abruptly acuminate at the apex, obliquely cordate or truncate at the entire base, sharply serrate, thick, dark green and glabrous above, densely pubescent beneath with soft white hairs which are sometimes deciduous by autumn; petioles and primary veins glabrous, often glaucous. The pedunculate bract is $10–12^{cm}$ long, oblong or spathulate, rounded at the apex, rounded or acute at base, sessile or nearly so, glabrate above, often soft-pubescent beneath. The flowers, which appear about the middle of June, are smaller than those of *Tilia heterophylla*, and the sepals and peduncles more pubescent than in that species. The ovary and young fruit are densely pubescent with short brown hairs; the mature fruit is $5–7^{mm}$ thick, globular or somewhat thicker than long, and not pointed.

From *Tilia heterophylla*, which it much resembles and with which it is often associated, *Tilia eburnea* is separated by the softer and looser pubescence on its foliage, its smaller flowers, somewhat earlier time of flowering, and the coarse brown tomentum of the ovary and fruit which is in strong contrast to the very close cinereous pubescence that clothes the fruit of *T. heterophylla*. From *T. pubescens* it is distinguished by having larger flowers, glabrous twigs, larger and broader foliage which is white (not gray or brown) pubescent beneath.

Tilia eburnea is found from middle North Carolina to northern Georgia between 200^{m} and 700^{m} elevation, on rich moist soil near small streams or on steep cool slopes. It is usually associated with the red oak, red maple, white ash, and yellow poplar, but is nowhere a common tree. In the cool hollows of the Blue ridge in North and South Carolina it occurs with the white linden and another related species which seems to be undescribed.

Crataegus cibilis, n. sp.—A tree 4–6^{m} in height, with a short unarmed trunk having dark gray nearly black scaly bark, and numerous long spreading branches forming a globose crown. Twigs soon glabrous, thick, soft, russet or red-brown, straight or nearly so, armed with very few short thorns 2–3^{cm} long. Leaves thin, on the upper surface bright green and glabrous except on the midrib, on the lower somewhat paler and sparingly pubescent, especially on the veins; the blades ovate deltoid or nearly orbicular, 7–9^{cm} long, 5–8^{cm} wide, rounded or truncate at the usually entire base, subacute or obtuse at the apex, sharply doubly serrate and with 2–4 pairs of short notches above the middle; petiole slender, one-half the length of the blade, villous. Inflorescence a nearly simple 4–8-flowered cyme; pedicels slender, erect, villous, the lower elongated. The flowers, which appear at Hot springs, North Carolina, early in May or the last of April, when the leaves are about half grown, are 20–24^{cm} wide; calyx large, cup-shaped, glabrous, the elongated ligulate or narrowly triangular sharply serrate lobes spreading or ascending after anthesis; stamens 20, anthers nearly white. The fruit, borne in nearly simple clusters, on long spreading or drooping nearly glabrous pedicels, and falling with the pedicels attached before or with the leaves in October, is depressed globose, 12–15^{mm} thick and not quite so long, concave at the base, full and rounded at the apex, dark red, capped by the large ascending calyx lobes; the cavity broad and deep; flesh thick, firm, yellow, sweet; seeds usually 5.7–8^{cm} long, lateral faces nearly plane, grooved on the narrow back.

The species above proposed is related to *Crataegus altrix*, proposed below, from which it is separated by the differently shaped foliage, and larger glabrous ascending calyx lobes. It occurs on the banks of the French Broad river in Madison county, North Carolina, and Indian creek, Unicoi county, Tennessee.

Crataegus altrix, n. sp.—Arborescent, 5–7^{m} in height, with a short usually unarmed trunk 1–2^{dm} thick, dividing above into numerous horizontal or spreading sparingly armed branches which form a globose or flattened crown; the bark on the trunk dark brown and broken by shallow furrows into narrow ridges, that on the branches light gray and smoother. Twigs brown, stout, glabrous, or nearly so, soft and brittle, somewhat geniculate, armed with few short (2–3^{cm}) thorns. Leaves ample, dark green and nearly glabrous above, more or less soft-pubescent on the lower surface, the blades ovate or broadly ovate,

$7-13^{cm}$ long, $5-11^{cm}$ wide, rounded or truncate at the serrate base, acute or obtuse at the apex, sharply and coarsely serrate or doubly serrate, with a pair of prominent notches at the base, and often less conspicuous notches above, 6–8 pairs of prominent veins, the lowest pair spreading; petiole terete or nearly so, at first pubescent, at length nearly glabrous. Inflorescence a several-flowered somewhat compound cyme; pedicels strict, erect, at first pubescent, soon glabrate; calyx large, cup-shaped, soon glabrate, the oblong glabrate serrate or nearly entire lobes reflexed after anthesis and often deciduous before the fruit falls; flowers about 20^{mm} wide; stamens 20; anthers white; styles 4–5. The fruit, which falls in September or October before the leaves, borne in simple, few-fruited clusters on nodding or declined pedicels, is glabrous, globose, $13-18^{mm}$ thick, bright glossy red, sparingly glaucous, and often capped by the persistent reflexed lobes; flesh thick, deep yellow, very sweet; seeds 4–5, nearly central in the fruit, $6-7^{mm}$ long, somewhat grooved on the narrow back, the lateral faces plane.

The type material was collected by the writer along streams and in pastures in northern Illinois. *Crataegus altrix* is evidently related to *C. canadensis* Sarg., but has much larger foliage and fruit. It is more closely related perhaps to *C. cibilis*, above proposed, of the southern Appalachians.

Crataegus obtecta, n. sp.—A tree $3-5^{m}$ in height, with a short usually unarmed trunk covered with dark gray or nearly black rough or scaly bark, and with long spreading branches which form a round or flat-topped crown. Twigs at first villous with matted gray hairs, at length glabrate, thick, soft, russet-brown, straight or nearly so, armed with few short thorns. Leaves thin for the group even when mature, above dull green and at first pubescent, but soon glabrate, beneath soft pubescent; the blades ovate in outline, $7-12^{cm}$ long, $6-9^{cm}$ wide, rounded or broadly cuneate at the entire base, acuminate at the apex, sharply and coarsely doubly serrate, seldom notched; petiole slender, villous. Inflorescence a nearly simple 5–10-flowered villous cyme; the flowers, which appear in northern Illinois from the 1st to the 10th of May (early for the group) when the leaves are about half grown, are about 2^{cm} wide; calyx large, obconic, villous, the elongated triangular lobes pubescent, sharply glandular, serrate, spreading after anthesis; stamens 20, anthers white. The fruit, borne in usually simple clusters on long spreading villous or nearly glabrous pedicels, is pyriform $12-15^{mm}$ thick, dark red, glabrate except at the apex, capped by the

large ascending nearly sessile calyx-lobes; cavity broad and deep; flesh thick, yellow, very sweet; seeds usually 5, 6–8^{mm} long, grooved on the back, the lateral faces nearly plane.

The species above proposed is related to *C. mollis*, from which it is separated by the different outline of the leaf, with its very sharp serratures, more simple inflorescence, somewhat later period of flowering, and larger erect calyx-lobes. The fruit matures early in October and falls early.—W. W. ASHE, *Raleigh, N. C.*

BLACK ROT OF ORANGES.

A FUNGOUS disease of navel oranges has attracted attention in the orange-growing districts of California for the past eight or ten years, and was named black rot by the writer on account of the color of the diseased tissues. The losses due to this disease will run from 3 to 10 per cent. of the navel crop, and as the cultivation of the navel variety in the state is extensive the total losses are proportionately heavy.

Oranges are attacked through the navel, the fungus hyphae entering cracks or other imperfections of the peel of those parts. The cells of the pulp sacks are destroyed, and soon become black in color and bitter to the taste. The peel is left uninjured until the disease has made considerable progress within, but finally becomes thin and darkened in color over the affected parts. The fungus vegetates freely among the pulp sacks, which are wholly destroyed as far as the mycelium extends, but this destruction of tissue rarely involves more than one-fourth of the fruit, and is commonly confined to the tissues lying near to and at one side of the navel. Infected fruit ripens prematurely, showing an exceptionally high color, and soon falls from the tree.

The fungus inducing this disease is a new species of Alternaria, and its conidia are produced upon the surface of the affected tissues. The life cycle has been studied by means of single spore cultures, and detailed descriptions and illustrations are reserved for publication, together with facts relative to preventive treatment. The following specific characterization may be accredited to Ellis and Pierce.

Alternaria citri, n. sp.—In oranges in California. Effused, olivaceous, becoming nearly black. Mycelium abundant, loosely interwoven, gray, consisting of slender, septate, yellowish or olivaceous-hyaline threads, penetrating and overrunning the matrix, much

branched, the branches mostly a little swollen at the apex and bearing the terminal variously shaped conidia, which are obovate, oblong-elliptical or subglobose at first, $10-22 \times 8-15\mu$ diam., and mostly 3-septate, finally large, $25-40 \times 15-25\mu$, short-clavate-oblong, 4–6-septate and slightly constricted at the septa, the cells divided by one or more longitudinal septa, dark olive-brown. The conidia are oftener 3–6-catenulate in series, either simple or branched. As shown by cultures, secondary conidia often arise directly from the primary, thus giving rise to a secondary series. The cells of the conidia at maturity incline to assume a spherical shape, and the conidia then resemble somewhat asci filled with globose sporidia.

From its habitat (inside the orange) and the character of the conidia this seems distinct from *A. tenuis* Nees, on orange leaves.—NEWTON B. PIERCE, *U. S. Dept. Agric., Bureau of Plant Industry, Pacific Coast Laboratory, Santa Ana, California.*

CURRENT LITERATURE.

BOOK REVIEWS.

The mutation theory.[1]

CONTRIBUTIONS TO the theory of evolution have been many, but in these later years progress has been very slow, largely because philosophical speculations and acrid discussions have dominated facts. The chief value of this great work of De Vries is that it makes a constant appeal to experiment and careful observation. The volume before us is but half of his work, doubtless the more important half, since it contains the brilliant experimental work which has led the author to present to the world his theory of the origin of species. The second volume is to deal with the principles of hybridization.

The theory of mutation is not new. Darwin recognized it especially in his earlier works, holding that "single variations" or sports have to be reckoned with, as well as natural selection. Through the influence of Wallace and others, natural selection has in most quarters come to be the ruling theory, though the importance of other factors has frequently been emphasized. As long ago as 1864 Kölliker appealed to heterogenesis, which is identical with mutation; the term "mutation" has been used by Scott and various writers, and the term "saltatory evolution" has been used by still others. Mutation involves the sudden origin of a new species without transitions or connecting links. Not all natural selectionists would find fault with this, since Darwin fully recognized the fact that selection improves rather than creates. Some selectionists, however, have held that natural selection is in reality a creative force, and to such De Vries has little comfort to give. Indeed, he discards natural selection altogether, so far as the evolution of species is concerned. Numerous experiments by the author and others show that there is a definite limit to individual variability, and that the full advantage of selection along any one line can usually be obtained within a very few generations, as in the parsnip or carrot. Again he claims that selection never fixes a character, but that reversion occurs after any number of generations of culture; apparent exceptions to these principles are due to hybridization or mutation. Thus natural selection can never create anything new; it can improve only within definite and narrow limits, and this improvement is possible only in artificial conditions. Mutation, on

[1] DE VRIES, HUGO: Die Mutationstheorie. Versuche und Beobachtungen über die Entstehung von Arten im Pflanzenreich, Vol. I. 8vo, pp. 648, with eight colored plates and many text figures. Leipzig: Veit & Co., 1901. See also Rev. Gén. Bot. 13:5–17. 1901.

the other hand, brings into existence something altogether new, the mutant remains fixed from the outset, and if it is fit, it will survive the struggle for existence as a new species. Mutability and variability are sharply contrasted; variability is obviously governed by external factors, especially nutrition, while mutability has no such obvious connection. Thus we may say that most species are fixed and immutable, yet more or less variable from their origin to their final extinction.

De Vries accepts Jordan's idea of species, viz., that within the Linnean species there may be "elementary species" (varieties, of authors), which are experimentally immutable. Jordan found about 200 immutable forms within the ordinary species limits of *Draba verna;* hence the idea that *Draba verna* is a collective group, and that the 200 immutable forms represent true species. In such cases the author favors a trinomial nomenclature.

Of a number of natural species studied, *Oenothera Lamarckiana* was the only one which appeared to be in a state of mutability. This species was found naturalized on a field near Hilversum, Holland, about 1875, and has increased its area rapidly. When first observed by De Vries in 1886, two elementary species were noticed among the normal forms, and were named by the author *Oenothera brevistylis* and *laevifolia*. Since that time these forms have maintained themselves, in spite of hybridization and the struggle for existence. From 1886 until now De Vries has made observations in the field at Hilversum, and has made almost innumerable cultures in the botanical garden at Amsterdam.

The experimental results may be briefly summarized. Out of 50,000 seedlings of *Oenothera Lamarckiana* in the various years of study, 800 or about 1.5 per cent., were mutants, while 98.5 per cent. came true to seed. Of these 800 mutants, more than one fourth belonged to the new species, *Oenothera lata*, *i. e.*, this species appeared anew in cultures more than 200 times; on the other hand *Oenothera gigas* appeared but once. From a great many other new species the author selected the most promising for further study. The new species have proved to be quite distinct from one another and from the parent species, not only in one but in several characters. De Vries shows in an exhaustive and satisfactory fashion that his new forms are as fully entitled to specific rank as any of the Onagra group of Oenothera (*e. g.*, *O. biennis*, *Lamarckiana*, *muricata*, *cruciata*, etc.). Indeed, it is possible to identify most of the species with certainty, as early as the rosette stage, some species having round and others grasslike leaves. The mutations are planless, occurring in all possible directions, involving all plant organs. Some of the mutants appear to have improved upon the parent forms, but in most instances this is not the case. The great majority of the mutants are constant from the outset; there is no fixation of their characters by selection, nor is there any reversion. There are no transitions between parent and offspring. One extremely interesting result is that the mutants

themselves show occasional mutations, and in many cases the same species has arisen from different parents. There follow theoretical considerations which may be omitted here, except to state that De Vries believes in periodic mutability, since most species now appear to be immutable. What causes mutability can only be conjectured; perhaps it is favored by generations of excellent nutrition, perhaps by alternations of diverse conditions.

About half of the first volume deals more indirectly with mutation. One section treats of nutrition and selection, another with the origin of garden varieties, the author finding general agreement in a number of cases with his work on Oenothera.

Independently and all but simultaneously with De Vries, Korschinsky[2] has brought together a vast mass of data under the title *Heterogenesis and Evolution.* From the records of gardeners and horticulturists, he has attempted to show that most of the culture "varieties" have arisen through heterogenesis and not by means of selection. Such evidence is not very trustworthy in special cases, but perhaps the mass of detail by its mere quantity may help to strengthen the case as a whole. In any event such evidence and the fact that it is brought forward independently gives support to the work of De Vries. Solms-Laubach[3] has presented evidence to show that *Capsella Heegeri* has arisen as a sport from *C. Bursa-pastoris.* Carlson[4] thinks similarly for some Swedish forms of *Succisa pratensis.* C. A. White[5] reports cases of mutation in the Acme tomato. In a most admirable paper on the present condition of our knowledge as to the origin of species, Wettstein[6] holds that several theories are tenable, but that among them all that of heterogenesis seems most important. He gives some of his own observations in support of this theory. Moll,[7] in an extended and highly appreciative review of De Vries's work, says that this is easily the most important work on evolution since Darwin's *Origin of Species.* Schumann[8] holds that this is the first work that has really established the evolution theory; he also accepts the Jordan-De Vries concept of species and the system of trinomial nomenclature.

It is much too early, of course, to venture a final opinion as to the true value of this work. That it is one of the greatest of all contributions to the literature of evolution is certain. That it will lead to a flood of experimental investigation is assured, and perhaps this will be the author's greatest service to the world. Whether natural selection has had its day, whether mutation is the dominant method of the origin of species, and whether Jordan's "ele-

[2] Flora **89** : 240–363. 1901.

[3] Bot. Zeit. **58**[1] : 167–190. 1900.

[4] Bot. Not. **1901** : 224–226.

[5] Science **14** : 841–844. 1901.

[6] Ber. Deutsch. Bot. Ges. **18** : Generalversammlungsheft 184–200. 1900.

[7] Biol. Cent. **21** : 257–269; 289–305. 1901.

[8] Bot. Cent. **87** : 170. 1901.

mentary species" will replace the "collective species" of Linnaeus are questions that must be left for the future to answer.—H. C. Cowles.

MINOR NOTICES.

Edgar W. Olive has[9] published a preliminary enumeration of the Sorophoreae, in advance of a more extended paper on the Acrasieae and their allies. Twenty-five species are presented, only one member of the group having been heretofore reported from America. A new genus (*Guttulinopsis*) is characterized, containing three species, and five other new species are described.—J. M. C.

The fourth fascicle[10] of the list of the genera of seed plants according to the Engler sequence has just appeared. The general character of the work was stated in this journal[11] in the notice of the first fascicle. In the present signature 1340 genera are listed, bringing the total number up to 5182. This fascicle begins with Dipteryx (Leguminosae) and ends with Cochlanthera (Guttiferae).—J. M. C.

The seventh part of Engler's *Pflanzenreich* has appeared,[12] and contains the Naiadaceae (family 12 of the spermatophyte series), by A. B. Rendle. The preliminary discussion is in English, and deals with the vegetative organs, anatomy, floral structure, geographic distribution, etc. The single genus *Naias* is presented as including thirty-two species, *N. marina* comprising sixteen named varieties.—J. M. C.

Parts 211 and 212 of Engler and Prantl's *Natürlichen Pflanzenfamilien* have appeared.[12] The former contains the Lepidodendraceae, Bothrodendraceae, Sigillariaceae, and Pleuromoiaceae, by H. Potonié, and the beginning of Isoetaceae by R. Sadebeck. It is interesting to note that in Potonié's scheme of phylogeny the Lepidodendraceae give rise to the Araucarieae, and these in turn to the other conifers. Part 212 contains the Dicranaceae, Leucobryaceae, Fissidentaceae, Calymperaceae, and Pottiaceae by V. F. Brotherus.—J. M. C.

Ohio fungi exsiccati, briefly noticed last month, are being issued in small fascicles by Professor W. A. Kellerman, of the Ohio State University. They are not sold, but distributed to mycological students and collectors making exchanges. The first fascicle, issued November 20, 1901, contains sixteen numbers, the specimens being ample and well packeted. Eight of these numbers belong to the Uredineæ, and the remainder to various para-

[9] Proc. Amer. Acad. 37 : 333–344. 1901.

[10] Dalla Torre, C. G. de, and Harms, A.: Genera Siphonogamarum ad systema Englerianum conscripta. Fasciculus quartus (signatura 31–40). Small 4to, pp. 241–320. Leipzig: Wilhelm Engelmann, 1901. *M* 4.

[11] Bot. Gaz. 30 : 67. 1900.

[12] Press of Wilhelm Engelmann, Leipzig.

sitic micro-fungi. Beside the usual data on the labels some synonymy is given, and also the original description of the species *verbatim et literatum.* An entirely new feature of the distribution, and one to be commended highly, is the exact reproduction of the labels in the form of a journal article, to be distributed as separates. The first issue is in the *Ohio Naturalist* (**2** : 135–140) of last November. Beside the labels, there is a page of introductory matter.—J. C. ARTHUR.

THE *Bulletin de l'Herbier Boissier* has undertaken to publish a card index[13] of the new species appearing since January 1, 1901. The cards are intended to be intercalated with those published in this country by Miss Josephine E. Clark. Unfortunately they are printed in sheets upon thin paper and are perforated for separation. The light weight of the stock, the uneven size of the cards, and the ragged perforated edges will certainly prove exasperating to those who undertake to insert these among any standard series of cards. The data furnished will be extremely valuable, but we fear the form of the publication will nullify the laudable intentions of the editor. —C. R. B.

NOTES FOR STUDENTS.

GIOVANNOZZI has studied[14] the mechanism and functions of hygroscopic movements in plants. Among the topics treated are movements of floral bracts and anthers, leaf movements, opening and closing of fruits, torsion of awns, movements of the branches of conifers, dispersal of spores. Most commonly there is an unequal swelling of neighboring tissues, sclerenchymatous cells in particular possessing great capacity for taking up water.—H. C. COWLES.

DR. A. ZIMMERMANN has discovered in the "scattered, large, thickened, hard warts" described by Trimen in *Pavetta indica*, as well as in some other allied species of Rubiaceae, the presence of masses of bacteria which penetrate into intercellular spaces of the leaves while they are still very young and there develop into huge masses. The presence of these bacteria produces the wart. What are the relations between the two organisms remains for later experimental investigation.[15]—C. R. B.

MITOTIC PHENOMENA in the flagellate, Polytoma, are described by

[13] Index botanique universel des genres, espéces et variétés de plantes, parus depuis le 1er janvier 1901. Publié par le Bulletin de l'Herbier Boissier, Chambésy, suisse. 25 fr. par an. Suite à Index Kewensis. Ces fiches sont destinées à être intercalées avec les "Card-Index Clark" américaines.

[14] Nuov. Giorn. Bot. Ital. **8**: 207–237. 1901.

[15] ZIMMERMANN, A.: Ueber Bakterienknoten in den Blättern einiger Rubiaceen. Jahrb. Wiss. Bot. **37**: 1–12. *figs. 1–9.* 1901.

Prowazek.[16] Of special interest is his account of a nuclear centrosome somewhat similar to that described for Euglena and some other flagellates. A minute body makes its appearance in the nucleus, moves to the periphery, and is thrown out, surrounded by a clear area of protoplasm. The body then divides and the daughter centrosomes, taking position at opposite ends of the elongated nucleus, become the poles of the spindle.— B. M. DAVIS.

ITEMS OF TAXONOMIC INTEREST are as follows: CARL PURDY (Proc. Calif. Acad. Sci. III. Bot. **2**: 107–150. *pls. 15–19.* 1901) has published a revision of *Calochortus*, not including the Mexican species. He recognizes 40 species, describing 5 as new.—T. D. A. COCKERELL (Torreya **1** : 142–143. 1901) has proposed a new genus (*Hesperaster*) founded on *Bartonia decapetala* Sims (not the earlier *Bartonia* Muhl.) to include also certain species heretofore referred to *Mentzelia*. Under this new generic name 9 species are placed.—J. C. ARTHUR (Bull. Torr. Bot. Club **28** : 661–666. 1901) has begun a series of publications entitled "New species of Uredineae," the first installment containing 12.—ALICE EASTWOOD (*idem*, 667–674) in publishing some notes on Californian species of *Delphinium* has described 4 new species. —J. M. C.

J. W. MOLL[17] has devised an apparatus for focusing the projecting microscope from a distance. In order to give the demonstrator at the screen control over the focusing arrangement when very high magnification is desired, he arranged, after the object has been brought to approximate focus, to change the focus by sliding the ocular in and out. The ocular is fixed to a sliding block and is entirely independent of the part carrying the objective. A wire cord, attached to the front of the ocular carrier, passes around a pulley, thence over another pulley fixed to the ceiling, then to a wheel and axle arrangement near the screen. A cord with an adjustable handle is attached to the wheel. Two stout spiral springs in front of the ocular carrier return it into place when the tension of the cord is relaxed. The arrangement enables the demonstrator to control the focusing from any position near the screen.—W. J. G. LAND.

I. KOSIŃSKI has published in a recent number of Pringsheim's *Jahrbücher* a paper on the influence of various conditions on the respiration of *Aspergillus niger*.[18] It appears that when the fungus is deprived of food respiration very promptly diminishes. Growth is suspended at the same

[16] PROWAZEK: Kerntheilung und Vermehrung der Polytoma. Oester. Bot. Zeits. **51** : 51. 1901.

[17] Proc. Roy. Soc. Amsterdam **4** : 95–101. *1 pl.* 1901.

[18] I. KOSIŃSKI: Die Athmung bei Hungerzuständen und unter Einwirkung von mechanischen und chemischen Reizmitteln bei *Aspergillus niger*. Jahrb. Wiss. Bot. **37**: 137–204. 1901.

time, beginning again, with the increased respiration, upon the return of nutriment. A sudden increase in the concentration of the surrounding medium decreases the respiration, and *vice versa.* Severe mechanical injury accelerates respiration, as shown much better by Richards for phanerogams. Respiration is accelerated by the presence of zinc, iron, and manganese, cocaine, strychnine, and sufficiently dilute ether. The variation in the results (CO_2 evolved) from hour to hour is so excessive in many of the tables that if the conclusions should be called seriously in question they would be found supported here by very weak evidence.—E. B. COPELAND.

IKENO describes [19] conditions of spore formation in Taphrina that suggest the need of further studies of this type and other members of the Exoasceae. Two nuclei, present in the young ascus, unite to form a large nucleus characterized by a conspicuous nucleolous. The latter appears to be chromatic in character. The nuclear membrane shortly disappears and the chromatin body proceeds to fragment. Ikeno found no mitotic phenomena. The chromatin globules simply split up until a number are present in the cytoplasm. These small chromatin bodies then gather in groups in a common vacuole. Each body takes to it a certain amount of cytoplasm and a membrane formed around the whole completes a spore. The spores later multiply greatly by budding. It should be noted that Ikeno has failed to find here the process of spore formation described by Harper in the ascus, nor is there yet the progressive cleavage characteristic of the Phycomycetes.—B. M. DAVIS.

PART of the recent literature on the physiology of reproduction is summarized by Klebs [20] and utilized as the basis of an estimate of the most promising lines of work for the immediate future. The influence of light, transpiration, and various foods on the initiation of the reproductive processes have so far been found reasonably constant. But to justify generalization there is urgent need of a physiological study of reproduction in a considerable number of phanerogams. Conditions which do not directly affect the initiation of the reproductive processes may greatly influence their subsequent course. Growth and reproduction are in antagonism to the extent that either, under favorable conditions, demands all available plastic matter. The demands of growth on any external condition are less strict than those of reproduction. Klebs brings up more points in his condensed fifteen pages than can even be mentioned in a review—among them, the relation of heredity and environment as controlling factors; the interrelation of various modes of reproduction (a question of minor importance among higher plants); double fertilization and xenia. The possibility is pointed out, and it seems to the reviewer little short of a certainty, that we must yet recognize cases in

[19] IKENO: Spore formation in Taphrina. Flora 88:229. 1901.

[20] KLEBS, G.: Einige Ergebnisse der Fortpflanzungs-Physiologie. Ber. Deutsch. Bot. Gesells. 18:201–215. 1900.

which the hereditary character of the male gametes has an influence outside of either embryo or endosperm, in the seed coats and fruit.— E. B. COPELAND.

THE effect of various kinds of nutrition on the formation of enzymes has been carefully considered by Went in experiments on *Monilia sitophila*.[21] This fungus he had previously studied in Java and fully described in *Centralblatt für Bakteriologie* 72: 1901, where also he discusses its culture in relation to different foods. It may develop ten different enzymes, all except trehalase formed in the culture fluid (though not all under like conditions), from which they may be precipitated by alcohol. They are malto-glucase (as Went prefers to name the enzyme which changes maltose into glucose), trehalase, raffinase, invertase, cytase, diastase, lipase, tyrosinase, lab enzyme, and trypsin. No retardation of the formation of the enzymes by the products of their activity could be observed in maltoglucase, invertase, diastase, or lipase.

The table below is an attempt to show diagrammatically the influence of the various materials upon enzyme development. More minute details as to the kinds of food tested must be sought in the paper itself. The sign + shows that the enzyme is formed with this food; the sign O, that it is not; –, that the case was not investigated.

	Casein	Peptone	Maltose	Raffinose	Glucose	Glycerin	Acetic acid
Lab enzyme	+	+	O	O	O	O	O
Trypsin	+	+	O	+ ?	O	O	O
Tyrosinase	+	+	+	+	+	+	+
Maltoglucase	+	+	+	+	O	O	O
Invertase	–	+	+	+ ?	+	+	+
Diastase	–	+	+	+	+	+	+

It is thus clear that in the same plant the different enzymes are affected differently by different foods. The danger of generalizing too widely from the few facts as yet ascertained is obvious. These experiments also help to do away with the idea, quite widely entertained, that enzyme development indicates a kind of starved condition of the cell. Usually it is only well nourished cells which develop much enzyme.— NINA G. HOLTON.

[21] WENT, F. A. F. C.: Ueber den Einfluss der Nahrung auf die Enzymbildung durch *Monilia sitophila* (Mont.) Sacc. Jahrb. Wiss. Bot. 36: 611–664. 1901.

OPEN LETTERS.

THE ACTION OF FUNGICIDES.

In Dr. Clark's[1] paper, in a recent number of the Botanical Gazette no attempt was made, as the author states, to discuss the literature of the subject; but Rumm[2] has written a paper that has such evident bearing on the subject that it should have received attention. The latter reached the following conclusion, based on experimental evidence closely resembling that adduced by Clark as indicating the solvent action on copper hydroxid of secretions or excretions from the cells: "Die Thatsachen, die uns Calcium und Kupferhydroxydmischungen ergeben haben, erklären sich leicht, wenn man annimmt, dass von Beginn der Einwirkung des Kupferhydroxyds an Spuren dieses Stoffes, welche durch aus den Algen austretende Säuren gelöst werden, wenigstens bis in die Wandsysteme der Algen vordringen und den Tod der letzteren bewirken." Rumm, however, failed to obtain the same results with Puccinia spores. It thus appears that the only difference between the explanation offered by Rumm and by Clark for the same phenomenon is that the former postulates an acid solvent excretion from the cell, while the latter has shown that saline or other organic substances probably produce the same effects.

Clark also failed to notice a short preliminary paper by the writer[3], in which are stated in outline results of investigation covering in substance every phase of the several factors affecting the action of fungicides on foliage which Clark mentions on page 44 of his paper, with the exception of the solvent action of the cell sap on copper hydroxid. The writer gave only part of the experimental data which he had obtained, but enough were given to substantiate the claim made here. A reference to the writer's paper will show the fact established that water must accompany copper hydrate or Bordeaux mixture on peach foliage in order to produce toxic effects.

[1] Clark, Judson F.: On the toxic properties of some copper compounds, with special reference to Bordeaux mixture. Bot. Gaz. 33: 26–48. 1902.

[2] Rumm, C.: Zur Kenntniss der Wirkung der Bordeauxbrühe und ihre Bestandteile auf Spirogyra longata und die Uredosporen von Puccinia coronata. Fünfstück's Beiträge 1: 81–156. 1897. A preliminary announcement of results occurs in Ber. Deutsch. Bot. Gesells. 13: 189–192. 1895, and another discussion of same experiments in Jahresh. Vereins vaterl. Naturk. Württemberg 54: 322–327. 1898.

[3] Bain, Samuel M., The injury of fungicides to peach foliage. Science N. S. 14: 221, 222. 9 Ag 1901.

The writer also made an experiment on peach leaves quite similar to the one described by Clark, in order to determine whether the leaf gives off any substance having a solvent action on copper hydroxid, and obtained results similar to those obtained by Clark. But these data do not *per se* show the solution of copper hydroxid by leaves in general, because of the presence of gum in the sinuses of the teeth of the leaf in question, apparently secreted by the marginal glands. This gum remains, or is freshly secreted during most of the functional life of the leaf, and must evidently be taken into account in drawing conclusions from the experiment as made by Clark. There can be little doubt, however, that soluble substances escaping from leaves into water on their surfaces will influence the solvent action of this liquid on copper hydroxid. De Saussure found that washing leaves with distilled water removes a considerable proportion of the alkaline salts contained in them, and Gaudichaud and Sachs found that drops of water standing on leaves soon acquire an alkaline reaction towards litmus.

It appears that Barth[4] was first to propose the theory of the action of fungicides on foliage which was stated by Clark. Droop and Wortmann[5] are said to have disproved Barth's theory, but the writer has not yet had access to their publications.

In conclusion, the statement may be permitted that the writer does not underrate the importance of Dr. Clark's paper as a contribution to our knowledge of the fungicidal action of the Bordeaux mixture.—SAMUEL M. BAIN, *University of Tennessee, Knoxville.*

REJOINDER.

In regard to the foregoing criticism of the treatment of the literature in my paper, I call attention again to the fact, which Professor Bain recognizes, that no attempt was made "to review the literature of the subject."[6]

In regard to Bain's preliminary paper, I may add that my paper was completed and in the hands of the publishers some weeks before his paper appeared in *Science*. I may also point out that his paper was not concerned with the problem as to how the Bordeaux mixture *effects its mission as a fungicide*—the chief object of my investigation of Bordeaux mixture; and that in regard to the injurious effect frequently observed on the leaves of the host plant, which I discussed incidentally on page 44, I simply brought together those factors which seemed to me to be of importance in this connection, without doing any experimental work except on the solvent action of the cell sap on the copper hydroxid deposited on the leaves. Barth's suggestion has reference to the effect of the mixture on the host plant only.—JUDSON F. CLARK, *Cornell University.*

[4] Bot. Centralbl. **61**: 268, 269. 1895. [5] Zeits. Pflanzenkrankh. **10**: 165. 1901.

[6] CLARK, JUDSON F., BOT. GAZ. **33**: 26. 1902.

NEWS.

DR. FR. CZAPEK has been promoted to full professorship in the Imperial German University of Prague.

DR. CARL E. CRAMER, professor of botany in the Swiss Polytechnic Institute at Zurich, died November 24, 1901.

DR. FRIEDRICH KRASSER has been appointed associate professor of phytopaleontology in the Imperial University of Vienna.

DR. F. W. NEGER, privat-docent in the University at Munich, has been called to a professorship in the Forest Academy at Eisenach.

AMONG THE forthcoming publications of the Clarendon Press is an authorized translation of Schimper's *Pflanzengeographie*, by Percy Groom and W. R. Fisher.

MISS SUSAN M. HALLOWELL, professor of botany in Wellesley College, has resigned the active duties of the post, which she has held since 1875, and has been appointed professor emeritus.

DR. J. R. GREEN, professor of botany to the Pharmaceutical Society of Great Britain, and author of several important books, has been elected a fellow of Downing College, Cambridge.

M. J. COSTANTIN, maître de Conférences à l'École normale Supérieure, Paris, has been made Professeur de Culture at the Museum d'histoire naturelle, in place of M. Maxime Cornu, deceased.

DR. A. FISCHER, privat-docent in the University of Leipzig, has been called to Basel to fill the chair left vacant by the death of Professor A. F. W. Schimper. He will begin his work there in April.

DR. EDWARD B. COPELAND has been appointed instructor in botany in Leland Stanford University. He will spend the remainder of the year at the University of Chicago, assuming his new duties in the autumn.

THE *Victorian Naturalist* states that a monument erected in memory of Baron Sir F. von Mueller, for nearly forty-five years government botanist of Victoria, was unveiled in November 26 by the Governor General.

MESSRS. HENRY HOLT & CO. are just putting through the press a second edition of *A manual of the flora of the Northern States and Canada*, by Nathaniel Lord Britton, Director of the New York Botanical Garden.

LONGMANS, GREEN & CO. have in press an elementary plant physiology by Dr. D. T. MacDougal. The rights in his *Experimental Plant Physiology*,

published by Henry Holt & Co., have been purchased by Longmans, and the plates have been destroyed.

THE VENERABLE DR. J. B. JACK, the well-known student of the Hepaticae, died suddenly on August 14, 1901, in the 84th year of his age. His collection, exceedingly rich in the forms of European species, was purchased some time ago by the Boissier herbarium.

THE SALE of the *Botanisches Centralblatt* does not affect the status of the *Beihefte zum Botanisches Centralblatt*, which since January has been the property of Dr. O. Uhlworm, and will be continued under the joint editorship of Drs. Uhlworm and F. G. Kohl.

THE NEW *Bulletin de l'Herbier* of the botanical institute at Bucharest, published under the direction of Professor Vladesco, indicates an awakening along botanical lines in Roumania. The articles are published in Roumanian and in French or German in parallel columns.

PROFESSOR W. J. SPILLMAN, formerly of the Washington Agricultural Experiment Station, has been appointed agrostologist of the United States Department of Agriculture to succeed Mr. F. Lamson-Scribner, who is now chief of the Philippine Bureau of Agriculture.

ANOTHER VOLUME has appeared in Engler and Drude's monumental *Vegetation der Erde*, viz., an exhaustive treatise of the Illyrian region by Dr. Beck. This volume, together with an earlier one on the Caucasus region by Dr. Radde, will be reviewed in the next issue of this journal.

THE ANNOUNCEMENT of the fourth annual session of the University of Montana Biological Station at Flathead lake has been issued. The session lasts from July 14 to August 16; among the courses offered is one by Mr. Harry N. Whitford, assistant in botany at the University of Chicago. A number of lectures and excursions are planned.

WE NOTE from the *American Naturalist* the following items: Dr. Georg Bitter has been appointed docent for botany in the academy at Münster. Dr. Julius Stoklasa has been made professor of plant production in the Bohemian technical school at Prague. Dr. Hans Winkler has been made docent for botany at the University of Tübingen. J. R. Jackson, keeper of the Museum of Economic Botany, and George Nicholson, curator of the Kew Gardens, have retired.

ALFRED W. BENNETT died suddenly at his London home on January 23, in his 69th year. He was author of the monograph on Polygalaceae for Martius's *Flora Brasiliensis*, translator (with Dyer) of Sachs's *Text-book of botany*, author (with Murray) of an excellent *Handbook of cryptogamic botany*, and also of a highly popular *Flora of the Alps*, besides numerous short papers. For many years he has been one of the editors of the *Journal* of the Royal Microscopical Society.

FROM BUDAPEST comes a new journal, *Magyar Botanikai Lapok*, under the editorship of Dr. Degen Árpád, A. F. Károly and Thaisz Lajos. As Hungary was the only European state without an independent botanical journal, it seemed good to the founders to fill this gap. The declared objects of the journal are: (1) to supply a medium for the publication of notes on Hungarian botany, especially the floristic and systematic features; (2) to secure to Hungarians recognition for their botanical work by presenting it properly to the world; (3) to keep Hungarians better informed of foreign investigations. Articles in the first number appear in Latin or Magyar; in the latter case they are also printed in German.

A NEW ENGLISH BOTANICAL JOURNAL made its début in January. Announced as the British Botanical Journal, it appears as the *New Phytologist*, and is to be issued monthly except in August and September, under the editorship of Professor A. G. Tansley, of University College, London. It proposes to be "a medium of easy communication and discussion between British botanists on all botanical subjects, ... for announcing discoveries or theories, ... notices of important new books and papers, ... inquiries, ... or statements of difficulties on topics theoretical or practical." No doubt British botanists will welcome a journal of such general scope and we hope that it will receive generous support. The first number shows an intent to carry out the ideas set forth by the editor. Typographically the number is open to much improvement, particularly in the arrangement of the contents.

THE MINNESOTA SEASIDE STATION party of 1902 plans to leave Minneapolis on July 12, just at the close of the meeting of the National Educational Association. It will proceed via the Canadian Pacific Railway to Vancouver, thence by steamer to Victoria, where a stop of a day will be made, and finally to Port Renfrew on the straits of Juan de Fuca, B. C., by coasting vessel. The party will return to Minneapolis about September 1, giving a month or more by the sea, and ample time for stops in the Rockies and Selkirks. The following staff is expected to organize the work of instruction and research: Conway MacMillan, of the University of Minnesota, director and lecturer on algology (Phaeophyceae); Raymond Osburn, of the University of Ohio, professor of zoology; K. Yendo, of the Imperial University of Tōkyō, professor of algology (Rhodophyceae); and Miss Josephine E. Tilden, of the University of Minnesota, professor of algology (Chlorophyceae and Cyanophyceae).

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UNDESCRIBED PLANTS FROM GUATEMALA AND OTHER CENTRAL AMERICAN REPUBLICS. XXIII.[1]

JOHN DONNELL SMITH.

(WITH PLATES X AND XI)

Ouratea Tuerckheimii Donn. Sm. (§ OOCARPAE Engl.)—Folia perelongate oblanceolato-oblonga in quarta parte superiore acutissime acuminata ad basin angustam obtusa praeter quartam partem inferiorem dense argutissimeque mucronato-serrata, venis transversis nervos conjungentibus subtus manfestis. Racemi paniculati folia fere aequantes, pedicellis 1–4-nis alabastra oblongo ovoidea plus minus superantibus. Sepala rigida lineari-oblonga petalis spatulato-obovatis paulo breviora. Gynophorum ovario vix longius, fructiferum obovoideum drupa globosa paulo minus.

Arbuscula omnino glabrata, ramis et paniculae axibus angulatis. Folia ad apicem versus ramorum 3–4-subverticillata coriacea generis adhuc ex longissimis 36–45^{cm} longa supra medium 8–11^{cm} basi 5–10^{mm} lata, nervis lateralibus crebris arcuatim ascendentibus marginem attingentibus, petiolis crassis canaliculatis 6–12^{mm} longis. Paniculae pyramidalis rami ascendentes, bracteis scariosis attenuato-lanceolatis 5–7^{mm} longis, pedicellis 10–13^{mm} longis, alabastris 8^{mm} longis, floribus 22^{cm} diametralibus (e schedula Tuerckheimiana Convallariae majalis odorem diffundentibus). Sepala persistentia medio crassiuscula et purpurascentia marginibus scariosa 10^{mm} longa, 3^{mm} lata obtusa, Petala 11–12^{mm} longa 6^{mm} lata. Antherae sessiles 9^{mm} longae. Gynophorum in anthesi 1^{mm} longum pentagonum. Drupa 9^{mm}-diametralis.—Ad *O. gigantophyllam* Engl. foliorum forma magnitudine venis, ad *O. podogynam* Donn. Sm. inflorescentia floribusque accedit.

[1] Continued from BOT. GAZ. 31: 125. 1901.

In sylvis ad Cubilquitz, Depart. Alta Verapaz, Guatemala, alt. 350^m, Maj. et Sept. 1901, *H. von Tuerckheim*, n. 7829 Pl. Guat. &c., quas edidit Donnell Smith.

EXPLANATION OF PLATE X.—FIG. 1, flowering branch.—FIG. 2, vertical section of flower.—FIG. 3, sepal.—FIG. 4, petal.—FIG. 5, anterior and lateral views of stamen.—FIG. 6, pistil.—FIG. 7, cross section of ovary.—FIG. 8, fruiting branch.—FIG. 9, vertical section of drupe.—FIG. 10, under surface of part of leaf.

Guarea Tuerckheimi C. DC.—Foliis modice petiolatis 5–8-jugis, foliolis oppositis petiolulatis lanceolato-oblongis basi aequilatera acutis apice longiuscule acuminatis acumine obtusiusculo supra glabris subtus ad nervos parce et adpresse pilosulis, paniculis fere e basi 2-partitis ramis inferne breviter ramulosis superne racemiformibus adpresse pilosulis, floribus modice pedicellatis, calyce obtuse 4-dentato petalisque 4 oblongis et apice acutis extus parce et adpresse pilosulis, tubo cylindrico glabro margine leviter crenulato, ovario styloque glabris.

Ramuli juniores adpresse pilosuli dein glabri et pallide fuscescentes lenticellis concoloribus. Folia usque ad 20^{cm} longa. Folia in sicco firmo-membranacea usque ad 15^{cm} longa et ad 5^{cm} lata pellucido-lineolata, nervis secundariis utrinque 8–10 subarcuato subadscendentibus. Rhachis subteres, junior adpresse puberula. Petioluli fere 5^{mm}, petioli 4^{cm}, pedicelli fere 2^{mm} longi. Paniculae florentes fere 16^{cm} longae. Petala in sicco rubescentia 6^{mm} longa 1.5^{mm} lata. Antherae 8 tubi denticulis oppositae infra ½ longitudinis affixae oblongae glabrae vix 1^{mm} longae. Ovarium conoideum gynophorum superans 4-loculare loculis 1-ovulatis. Stigma orbiculare.—Species *G. purpureae* C. DC. in DC. Monogr. Phan. 1: 564 (ubi adde: Peruvia, Pav. in herb. Boiss.) affinis.

Cubilquitz, Depart. Alta Verapaz, Guat., alt. 350^m, Aug. 1901, *von Tuerckheim*, n. 7835 Pl. Guat. &c., qu. ed. Donn. Sm.

Matayba clavelligera Radlk.—Arbor ramis teretiusculis, pilis minutis flavidis pulverulento-tomentellis, lenticellosis; folia abrupte pinnata; foliola 4–6, alternantia vel subopposita, superiora majora obovata, reliqua lanceolato-elliptica, omnia integerrima, petiolulata, membranaceo-chartacea, sicca supra sordide viridia, subtus subfusca, pilis minutissimis obverse clavelliformibus aliisque setulosis plus minus dibrachiatis sparsis glandulisque microscopicis praesertim subtus obsita, ceterum glabra, sparsim

pellucide punctata, hypodermate instructa; paniculae in apice ramorum axillares, elongatae, pulverulento-tomentellae; petala sepalis majora, bisquamata; discus puberulus; fructus turbinatus, 3-lobatus, lobo uno alterove abortu minore, styli reliquiis in stigma breviter divaricato-3-lobum terminatis apiculatus, in stipitem mediocrem loculis breviorem contractus, praeter basin pilis minutis adpressis laxe adspersam glabratus, endocarpio circa seminis insertionem tantum pilosa; semen arillo fere usque ad apicem obtectum.

Arbor ligno duro. Rami paniculas gerentes 4^{mm} crassi, cortice pallide subfusco lenticelloso. Folia circa 25^{cm} longa; foliola superiora $16–20^{cm}$ longa, 7^{cm} lata, inferiora fere dimidio minora. Paniculae $20–25^{cm}$ longae (ramis apice interdum fasciatis); bracteae bracteolaeque minimae; cymulae subsessiles, subglomeruliformes; pedicelli vix 2^{mm} longi, infra medium articulati, fructigeri 5^{mm} longi. Calycis profunde partiti lobi 1.5^{mm} longi, acuti, extus tomentelli. Petala oblonga, fere 2^{mm} longa, breviter unguiculata squamaeque spathulato-oblongae basi interdum connatae petala ipsa paullulum superantes villosiuscula. Stamina 3^{mm} longa, filiformia, inferne villosa, antherae subglabrae. Fructus vix semimaturus stipite 3^{mm} incluso 1^{cm} longus et latus.—Maxime affinis est *M. floribundae* Radlk. (in Sitzungsber. K. Bayer. Acad. **9**: 626. 1879) foliolis hypodermate instructis et pilis minutissimis obverse clavelliformibus aliisque setulosis plus minus dibrachiatis praesertim subtus obsitis, sed differt foliolis majoribus obovato- vel lanceolato-ellipticis (nec exactius oblongis) et cymulis subsessilibus (nec conspicue stipitatis).

Mazatenango, Guat., Jul. 1867, *Bernouilli et Cairo*, n. 3344.—Cubilquitz, Depart. Alta Verapaz, Guat., Dec. 1900, *von Tuerckheim*, n. 7979 Pl. Guat. &c., qu. ed. Donn. Sm.

SWARTZIA MYRTIFOLIA Sm., var. **Guatemalensis** Donn. Sm.—Folia et superiora et inferiora plerumque simplicia, rarius 3-foliolata, sicut foliolum terminale usque ad 19^{cm} longa 6.5^{cm} lata, petiolo communi late (5^{mm}) alato. Stamina majora 8. Ovarium 6–8-ovulatum.

Cubilquitz, Depart. Alta Verapaz, Guat., alt. 350^{m}, Maj. 1901, *von Tuerckheim*, n. 7839 Pl. Guat. &c., qu. ed. Donn. Sm.

Gurania megistantha Donn. Sm. (§ F. II. 2. Cogn. in DC. Monogr. Phan. **3**: 680.)—Caulis crassissimus cum pedunculis cirrhisque glaber. Flores masculini maximi racemosi, pedicellis gracilibus glabris. Calycis tubus e basi dilatata longissime cylin-

dricus segmentis attenuato-linearibus 4-plo vel ultra longior. Petala lineari-triangularia subulato-apiculata segmentis calycinis altero tanto fere longiora. Antherae anguste lineares tubi duas partes vel ultra aequantes, appendice lineari-triangulari antherae dimidium subaequante.

Caulis ligneus suberosus digitum crassus e nodis radices aërias fibrillosas longissimas emittens. Cirrhi striati 3–4^{dm} longi. Pedunculi singuli vel bini 7–13^{cm} longi, racemis 2.5–4^{cm} longis, pedicellis 1.4–5^{cm} longis. Calyx miniatus omnino glaberrimus, tubo 3.5^{cm} longo basi 6^{mm}, supra basin 4^{mm} lato, segmentis 8^{mm} longis 1.5^{mm} latis enerviis. Petala utrinque papillosa 15^{mm} longa 3^{mm} lata enervia. Antherae breviter replicatae tubi basin attingentes 20^{mm} longae, connectivo angusto cum loculis glabro, appendice utrinque papillosa. Florum nondum evolutorum tubus 2.5^{cm} longus, segmenta atque conniventia petala 8^{mm} longa, antherae 18^{mm} longae, appendix 8^{mm} longa. Folia, flores feminini, fructus deficiunt.—Haec species, quamvis quot poteram adipisci exempla foliis careant, tamen optime distincta, descriptionem merere videtur.

In silvis Suerrensibus, Llanuras de S. Clara, Cost., alt. 300^{m}, Apr. 1896, *Donn. Sm.*, n. 6649 Pl. Guat. &c., qu. ed. Donn. Sm.—Eandem plantam foliis delapsis legit *Tonduz* in collibus prope Sikúrbete, Talamanca, Cost., Febr. 1895, n. 9385 herb. nat. Cost.

Gonzalea bracteosa Donn. Sm.—Undique plus minus pilosa. Folia oblanceolato- vel obovato-oblonga arcuatim acuminata in basin acutam sensim angustata, stipulis lineari-triangularibus in vaginam petiolo longiorem connatis. Thyrsorum et axillarium et terminalium folia vix aequantium cymae dissitae sessiles brevissimae et cymulae bracteis bracteolisque pluribus foliaceis longissimis involucratae, floribus sessilibus 5-meris. Ovarium biloculare. Bacca globosa calycem aequans.

Frutex 3^{m} altus, caulibus thyrsisque dense appresseque pilosis, novellis et foliis nascentibus canescentibus. Folia supra praeter nervos mox glabrescentia subtus sparsim pilosa et pallidiora 15–21^{cm} longa 4–7^{cm} lata, nervis lateralibus utrinque 7–8, petiolis 5–9^{mm} longis, stipulis persistentibus 1.5–2^{cm} longis, vagina 7–10^{mm} longa. Thyrsi virgati pedunculo 3–7^{cm} longo addito 8–18^{cm} longi, bracteis bracteolisque lineari-lanceolatis vel linearibus 5–12^{mm} longis dense longeque pilosis, cymulis subsessilibus, floribus ternis nondum satis evolutis circa 4^{mm} longis. Calyx sericeus semiglobosus, dentibus triangularibus intus glabris. Corolla infundibularis praeter setulas erectas glabra, lobis intus et faucibus villosis. Ovarium disco superatum, ovulis paucis.

Bacca sucosa nigra 4^{mm} diametralis, pyrenis in utroque loculo 1–3 (omnibus in speciminibus suppetentibus abortu vacuis).

In silvis profundis udisque ad Suerre, Llanuras de S. Clara, Cost., alt. 300^{m}, Apr. 1896, *Donn. Sm.*, n. 6583 Pl. Guat. &c., qu. ed. Donn. Sm.

Psychotria polyphlebia Donn. Sm. (Sect. EUPSYCHOTRIA, § BRACTEOSAE Muell. Arg. in Mart. Fl. Bras. VI. V. 313).—Suffrutex humilis simplex ferrugineo-pilosus. Folia oblongo-obovata superne rotundata minutissime cuspidata in petiolum longum attenuata supra glabra et lineolis punctulata subtus pilosa, nervis lateralibus creberrimis supra prominentibus subtus immersis, venis obsoletis. Pedunculi axillares, capitulis obscure rameis multifloris, bracteis exterioribus ad basin ramorum sitis herbaceis oblongo-ovatis, interioribus subaequilongis oblongis. Calyx ovario stipitato superatus. Corollae tubus lobis 5-plo longior. Drupae cocci orbiculares valde compressi.

Caulis e basi radicante ascendens 12–24^{cm} altus superne pilosus, internodiis brevibus. Folia 11–16^{cm}, longa 5–7.5^{cm} lata, nervis lateralibus utrinsecus 25–34 circa 3–5^{mm} inter se distantibus patulis subrectis parallelis sub margine conjungentibus, petiolis dense pilosis 2–6^{cm} longis, stipulis parvis subulato-bifidis deciduis. Pedunculi pilosi 2–3^{cm} longi. Capitula subhemisphaerica 7–12^{mm} alta basi 15–25^{mm} lata, bracteis haud coloratis discretis bracteolisque lineolatis sparsim piliferis, floribus 5-meris bracteolas involucrantes subaequantibus. Calyx denticulatus. Corolla alba extus sparsim pilifera, tubo tenuiter cylindrico in fauces nudas ampliato. Antherae lineari-oblongae exsertae. Drupae circa 10-aggregatae globosae carnosae coccineae, coccis osseis 7–9^{mm} diametralibus dorso leviter convexo sulcatis facie ventrali subconcava laevibus.

In silvis uliginosis Suerrensibus, Llanuras de S. Clara, Cost., alt. 300^{m}, Apr. 1896, *Donn Sm.*, n. 6854 Pl. Guat. &c., qu. ed. Donn. Sm.— In declivibus silvestribus montis *Tsaki*, Talamanca, Cost., alt. 500^{m}, Apr. 1895, *Tonduz*, n. 9577 herb. nat. Cost.

Cestrum Poasanum Donn. Sm. (Sect. EUCESTRUM, § I. Dun. in DC. Prodr.).—Glabrum. Folia longiuscule petiolata e basi optime rotunda sensim acutissimeque lanceolata subtus pallida, nervis subtus prominulis fuscentibus, lateralibus arcuatim longeque ascendentibus, areolis subtus conspicuis majusculis. Flores paniculati pauci-aggregati, pedicellis vix ullis bracteolatis. Calyx badius, denticulis subulato-apiculatis. Corollae violaceae tubus

subcylindricus et calyce et lobis propriis 5-plo longior. Filamenta breviter adnata ibidem et loco egressus minutissime appendiculato pubescentia.

Frutex 3–4^{m} altus articulatione foliorum nodosus, ramulis subflexuosis. Folia subcoriacea subtus granuloso-punctulata 8–12^{cm} longa 2.5–4^{cm} lata, nervis lateralibus fortioribus utrinsecus 6–8, petiolis 12–15^{mm} longis. Paniculae axillares et terminales folia vix aequantes, floribus ad apicem versus axium secundariorum 3–4-fasciculatis, bracteolis brevissime filiformibus. Calyx tubuloso-campanulatus 4^{mm} altus 2^{mm} latus, dentibus triangularibus. Corollae succulentae tubus tenuis nervosus e basi sursum paulatim ampliatus super ovarium haud constrictus 21^{mm} longus ad fauces 3.5^{mm} latus, lobi patentes utrinque violacei ovati acuti 4^{mm} longi. Genitalia tubo aequilonga. Filamenta e tertia parte superiore tubi libera et glabra, appendice oblonga 0.5^{mm} longa. Discus cupuliformis. Stigma concavo-discoideum. Drupa fusca globoso-ovalis 7^{mm} longa, seminibus 2–10, nonnullis saepius abortivis.—*C. nocturno* L. affine.

In fruticetis apertis declivium montis vulcanici *Poás*, Prov. Alajuela, Cost., alt. 2500^{m}, Mart. 1896, *Donn. Sm.*, n. 6674 Pl. Guat. &c., qu. ed. Donn. Sm.—Eadem planta sub n. 109 Endres in herb. Kew. exstat.

Columnea calcarata Donn. Sm. (§ ORTHOLOMA Benth.).—Glabra. Folia carnosa nitida parum disparia obovata apice ipsa acuminata in petiolum attenuata. Pedunculi solitarii flore 3–4-plo breviores. Calycis obliqui segmenta inaequalia lanceolata dorso valde carinato in pedunculum decurrentia. Corollae declinatae tubus calyce 5-plo longior in calcar productus supra tertiam partem cylindricam paulatim ampliatus, limbo subobliquo, lobis subaequalibus.

Frutex epiphyticus repens ramosus. Cujusque paris folium alterum 4–6^{cm} longum, 2–2.5^{cm} latum, alterum triente minus, nervis lateralibus utrinque 4–5 et venarum reticulis obscuris. Pedunculi 5-carinati 9–12^{mm} longi. Calyx 6^{mm} altus, segmentis utrinque pubescentibus, majoribus 3^{mm} longis. Corollae coccineae tubus calcare 5^{mm} longo addito 33^{mm} longus vix ventricosus, lobi circa 7^{mm} longi. Stamina ad 1^{cm} supra tubi basin affixa et ibidem pubescentia 18–22^{mm} longa basi in vaginam adnatum connatis, antheris subquadratis 2^{mm} latis, loculis late discretis ovalibus 1.5^{mm} longis. Disci glandula solitaria integra ovalis 2^{mm} longa. Ovarium pubescens oblongo-ovoideum 3^{mm} longum, stylo 27^{mm} longo, stigmate stomatomorpho. Fructus desideratur.

Cubilquitz, Depart. Alta Verapaz, Guat., alt. 350^{m}, Febr. 1900, *von Tuerckheim*, n. 7645 Pl. Guat. &c., qu. ed. Donn. Sm.

Bravaisia grandiflora Donn. Sm.— Praeter inflorescentiam glabrescens. Folia elliptica utrinque acuminata caudato-producta, venis obsoletis. Panicula folia aequans, bracteolis orbicularibus mucronatis. Calyx bracteolis 3-plo longior, segmentis oblongis mucronatis. Corolla violacea maxima calyce 5-plo longior ad tertiam partem lobata, tubo cylindrica supra calycem in limbum infundibularem ampliato, lobis oblongo-obovatis extus pilosis. Antherae triangulari-sagittatae. Ovarium 4-ovulatum.

Frutex, ramulis subtetragonis lenticellatis. Folia subcoriacea subtus densissime lineata ad apicem versus ramulorum 11–12^{cm} longa 4–4.5^{cm} lata in caudam 11–16^{mm} longam acuminata in petiolos 9–13^{mm} longos basi connatos decurrentia. Thyrsi in paniculam trichotoman subcorymbosam 14^{cm} altam foliaceo-bracteatam dispositi, axibus gracilibus, floribus aggregatis sessilibus, terminali bracteis e basi sessili ovata longissime lineari-productis fulto. Calycis segmenta paene sejuncta 9^{mm} longa obtusa cum bracteolis basi connatis subcoriacea apice carinata enervia flavo-pubescentia ciliata. Corolla 4.5^{cm} longa, tubo 10^{mm} longo, limbo 19^{mm} longo, basi 4^{mm} ore 10^{mm} lato, lobis 13^{mm} latis aestivatione sinistrorsum obtegentibus. Stamina basi barbata et dilatata annulo tenui piloso affixa, antheris 4^{mm} longis, loculis inferne mucronatis. Discus parum conspicuus. Ovarium oblongo-ovoideum. Stylus 27^{mm} longus, stigmatis lobo postico obsoleto. Capsula mihi non visa.

In silvis ad Sachichá, Depart. Alta Verapaz, Guat., alt. 1000^{m}, Apr. 1901, *von Tuerckheim*, n. 7924 Pl. Guat. &c., qu. ed. Donn. Sm.

Citharexylum pterocladum Donn. Sm.— Glabrum. Rami alato-quadrangulares. Folia membranacea oblongo-elliptica apice acutiuscula mucrunculata in petiolum attenuata laxe reticulata. Racemi ex axibus superioribus orti et in paniculam amplam dispositi, pedicellis calyce dimidio brevioribus bracteola bis terve longioribus. Calyx truncatus costis apiculatus. Corolla lilacina nervosa, tubo calycem bis superante lobis supra basin dilatatis paulo longiore.

Arbor silvestris, ramis fistulosis digitum minimum crassis, angulorum alis circa 2^{mm} latis, ramulis ultimis compressis. Folia opposita subfalcata 10–15^{cm} longa 3.5–6^{cm} lata supra minutissime atro-punctulata basi subobliqua glandulis 2 oblongis subtus foveolata, nervis purpurascentibus, lateralibus utrinsecus 6–7, petiolis 2–3.5^{cm} longis. Paniculae usque ad 30–40^{cm} altae, racemis erecto-patentibus 8–20^{cm} longis, floribus sparsis, pedicellis 2^{mm} longis, bracteolis subulato-triangularibus. Calyx tubuloso-campanulatus ore pubescens

ceterum glaber. Corollae praeter margines ciliolatos et fauces cano-villosas glabrae tubus 6^{mm} longus, lobi non satis aequales circa 4^{mm} longi basi 2^{mm} superne 3^{mm} lati reticulato-nervosi, 2 exteriores lineis 3 violaceis notati (ex oculatissimi repertoris schedula). Stamina 4 paulo infra fauces inserta subinclusa.—Ab *C. quadrangulari* Jacq. ramorum alis, foliorum retibus, corollae colore atque nervis insigniter differt.

Cubilquitz, Depart. Alta Verapaz, Guat., alt. 350^{m}, Febr. et Mart. 1901, *von Tuerckheim*, n. 7922 Pl. Guat. &c., qu. ed. Donn. Sm.

ARISTOLOCHIA ARBOREA Linden ex Hook. Bot. Mag. *t. 5295*. (§ GYMNOLOBUS; *Unilabiatae.*)—Fruticosa ramosa, ramis erectis velutino-setosis; petiolis 1^{cm} longis, foliis adultis crassiusculis superne glabrescentibus subtus, praecipue secus nervos, molliter setosis, 34^{cm} longis 10^{cm} latis oblique oblongo-lanceolatis longe acuminatis basi rotundatis 1-nerviis, nervis secondariis remotiusculis arcuatis; foliis junioribus subtus dense ferrugineo-tomentosis; pedunculis aggregatis e trunco suberoso supra terram emergentibus singulis $3–4^{cm}$ longis gracilibus; perianthio $8–9^{cm}$ longo basi tubulato, tubo superne oblique dilatato in limbum latum cordatum acuminatum venoso-bullatum expanso; fauce aperta processu marculiformi crassiusculo stipitato capitato, capite carnuloso, praedita; columna oblonga, antheris linearibus.—*A. maximam* Jacq. quoad habitum refert, foliis, perianthioque valde differt; processu capitato carnuloso e limbo emergente valde insignis.

De hac specie ita in litt. scribit oculatissimus repertor: "Kleiner Waldbaum; Blumen stets am Grunde des Stammes vorbrechend, braun, an der unteren Spitze weiss."

Cubilquitz, Depart. Alta Verapaz, Guat., alt. 350^{m}, Jul. 1901, *von Tuerckheim*, n. 7936 Pl. Guat. &c., qu. ed. Donn. Sm.

ARISTOLOCHIA PILOSA H. B. et K., var. **ligulifera** Mast.—A typo, ex confesso, valde variabili differt haecce varietas limbo perianthii ligulis nigrescentibus carnosulis superne dense vestito.

Cubilquitz, Depart. Alta Verapaz, Guat., alt. 350^{m}, Mart. 1901, *von Tuerckheim*, n. 7768 Pl. Guat. &c., qu. ed. Donn. Sm.

Haecce varietati forsan attribuenda: n. 2668 Bernouilli et Cario, Guatemala; n. 203 Endres, Costa Rica; n. 1271 Kalbreyer, Ocaña; n. 178 Wagner, Panamá, in herb. Monac.

Aristolochia securidata Mast. (§ GYMNOLOBUS: *Unilabiatae.*)

—Setulosa demum glabrescens, petiolis 3–4^{cm} longis, foliis subcoriaceis glabris 12^{cm} longis 7^{cm} latis cordato-oblongis abrupte acuminatis basi bilobis, lobis rotundatis sinu lato separatis, palmatim 5-nerviis, nervo medio crassiore, nervis lateralibus convergentibus arcuatis; perianthio 4^{cm} longo, tubo basi erecto ventricoso 1^{cm} longo, medio infundibuliformi aequilongo in limbum 3–4^{cm} longum hastato-triangularem nervosum producto; columna oblonga, antheris linearibus; stylis 6 oblongis ad margines recurvatis.—Forma perianthii omnino distincta.

Rosario, Llanuras de Santa Clara, Cost., alt. 300^{m}, Jul. 1899, *H. Pittier*, n. 7604 Pl. Guat. &c., qu. ed. Donn. Sm.

Piper calophyllum C. DC.—Foliis modice petiolatis ample ovatis basi aequilatera cordatis apice acuminatis supra ad nervos et subtus ubique hirsutis, nervo centrali paulo ultra ½ longitudinis suae nervos arcuatim adscendentes utrinque 9 mittente quorum infimi utrinque 3 magis approximati, petiolo usque ad limbum vaginante pedunculoque quam petiolus breviore hirsutis, spica florente cylindrica crassa apice mucronata quam folii limbus pluries breviore, bracteae vertice triangulari-truncato glabro, pedicello lato subcucullato utrinque villoso.

Ramuli hirsuti, amentiferi 11^{mm} crassi nodis hand tumidis, collenchymate haud vel parce et sparsius libriformi in fasciculos discretos disposito, fasciculis intramedullaribus permultis 1-seriatis. Limbi in sicco subcoriacei opaci et pellucido-punctulati circiter 29^{cm} longi et 19^{cm} lati. Petioli fere 4.5^{cm}, pedunculi 1^{cm} longi. Spica florens 6.5^{cm} longa et 6^{mm} crassa, mucrone fere 3^{mm} longo. Stamina 4 ovarii basi ima adnata, antheris reniformibus quam filamento multo brevioribus. Ovarium glabrum apice subattenuatum. Stigmata 3 sessilia linearia brevia et recurva. Bacca verisimiliter subtetragona. —Species sectionis *Steffensia* C. DC.

Cubilquitz, Depart. Alta Verapaz, Guat., alt. 350^{m}, 1901, *von Tuerckheim*, n. 7959 Pl. Guat. &c., qu. ed. Donn. Sm.

Mollinedia Costaricensis Donn. Sm. (§ APPENDICULATAE Perk.). —Folia utrinque sparsim appresse pilosa rotundo-obovata aut late ovalia abrupte brevissimeque acuminata basi actua supra medium remote minuteque denticulata. Cymae ad apicem versus pedunculi brevis fasciculatae simplices aut rarius breviter thyrsoideae cum perianthiis luteis pilosae. Perianthii ♂ lobi

ovati obtusi, interiores receptaculum vix superantes exterioribus paulo breviores appendice subquadrata dentata instructi, staminibus circa 22–28. Perianthium ♀ ovoideum, lobis triangularibus aequalibus, carpellis numerosissimis hemisphaericis. Drupae globoso-ovales.

Frutex 10–12^{m} (e schedula Pitterian arbuscula, corona depressa), ramulis novellis pilosis. Folia juniora pellucido-punctulata 6.5–10^{cm} longa 5.5–8^{cm} lata, aetate provectiore coriacea praeter nervos glabrescentia usque ad 16^{cm} longa et 10^{cm} lata, nervis fortioribus lateralibus utrinque 5–6, petiolis pilosis 1–1.5^{cm} longis. Cymae axillares et terminales petiolis paulo vel bis longiores bracteolatae, pedunculo 2–8^{mm} longo, axe primario nonnunquam evoluto, axibus secundariis 5–10^{mm} longis, tertiariis trinis quam flores brevioribus. Perianthium ♂ obpyramidale 6^{mm} altum, lobis erecto-patentibus 3–3.5^{mm} longis, receptaculo intus glabro, antheris ovoideis breviter stipitatis, loculis confluentibus. Perianthium ♀ 9^{mm} altum, lobis 1.5^{mm} longis, receptaculo breviter cupuliformi 7^{mm}-diametrali sericeo alveolato, carpellis sericeis circa 48–54, stylo brevi. Drupae subessiles in specimenibus suppetentibus abortione solitariae 1^{cm} longae deraso indumento glabrescentes.—Juxta methodum in Monographia clari Perkins expositam prope *M. Boliviensem* A. DC. collocari debet.

La Emilia, Llanuras de Santa Clara, Cost., alt. 250^{m}, Apr. 1896, *Donn. Sm.*, n. 6760 Pl. Guat. &c., qu. ed. Donn. Sm.—Tuis probe Turrialba, Prov. Cartago, C. R., alt. 620^{m}, Maj. 1897, *Pittier*, n. 11.250 herb. nat. Cost.—In pascuis ad Aragon, Prov. Cartago, C. R., alt. 630^{m}, Jan. 1899, *Pittier*, n. 13.226 herb. nat Cost.—In silvis ad Las Vueltas, Tucurrique, C. R., alt. 650^{m}, Maj. 1899, *Tonduz*, n. 13.365 herb. nat. Cost.

Ocotea Palmana Mez et Donn. Sm.—Foliis rigidiuscule coriaceis, adultis supra praeter nervos primarios plus minus tomentellos glabratis, subtus adpresse tenuiterque tomentellis, latissime obovato-ellipticis, basi late acutis, apice acumine parvo latoque imposito rotundatis, penninervibus, subtus valde prominulo-retatis; inflorescentia dense ferrugineo-tomentosa foliis multo breviore; floribus hermaphroditis, dense tomentellis, perianthii tubo 0; filamentis subnullis; staminodiis deficientibus; ovario glabro stylum papillosum crassum subaequante.

Ramuli dense adpresse ferrugineo-tomentelli. *Folia* petiolis plus minus 20^{mm} longis stipitata, plus minus 190^{mm} longa, 110^{mm} lata, supra costis venisque nonnullis immersis laevia, margine plana. *Inflorescentia* subpauciflora, squarrose breviter panniculata; pedicellis plus minus 3^{mm} longis, bracteolis

partim diu persistentibus lingulato-lanceolatis pedicellos superantibus. *Flores* hermaphroditi, 5–6^{mm} longi; limbi segmentis ovato-ellipticis, subacutis. *Filamenta* ser. I, II omnia subnulla, ser. III antheris bene breviora tomentosa glandulis binis magnis pallidis inter stamina ser. exteriorum collocatis praedita. *Antherae* suborbiculares, apice rotundatae, loculis 2 introsim 2 valde lateraliter fere extrorsim dehiscentibus. *Fructus* ignotus.

In sylvis prope La Palma, Cost., alt. 1500^{m}, Nov. 1898, *Tonduz*, n. 7374 Pl. Guat. &c., qu. ed. Donn. Sm. (n. 12652 herb. nat. Cost.).

Obs. Absque dubio Ocoteae Salvini Mez Guatemalensi peraffinis.

Ocotea Quisara Mez et Donn. Sm.—Ramulis apicem versus bene angulatis; foliis chartaceis, glaberrimis, optime ellipticis, basi breviter nunc brevissime acutis apice eleganter acuminatis, penninervibus, subtus tenuiter denseque prominulo-reticulatis; inflorescentia submultiflora, pyramidatim paniculata, minute cinereo-tomentella, foliis multo breviore; floribus hermaphroditis, adpresse tomentellis; perianthii tubo 0; antheris sessilibus, anguste ellipticis, apice rotundatis, papillosis; staminodiis bene evolutis stipiti-formibus; ovario glabro, ellipsoideo.

Ramuli apicem versus minute peradpresseque cano-tomentelli. *Folia* petiolis plus minus 20^{mm} longis, fere usque ad apicem in statu sicco insigniter nigricantibus stipitata, membranaceo-chartacea, paullo nitidula, plus minus 300^{mm} longa, 115^{mm} lata, margine fere plana. *Inflorescentiae* in ramulorum apice e squamarum deciduarum axillis provenientes; pedicellis vix ultra 4^{mm} longis bracteolis deciduis. *Flores* 4^{mm} longi; limbi segmentis ellipticis, rotundatis; antheris connectivo ultra locellos optime per paria superpositos producto apice rotundatis, ser. exteriorum absque dubio introrsis, ser. III basi glandulis binis globosis manifestis praeditis. *Ovarium* stylo crassiuscule cyclindrico subaequilongo, stigmate capitulato. *Fructus* ignotus.

La Concepcion, Llanuras de Santa Clara, Cost., alt. 250^{m}, Febr. 1896, *Donn. Sm.*, n. 6756 Pl. Guat. &c., qu. ed. Donn. Sm.—La Emilia, Llanuras de S. Clara, alt. $^{1}250^{m}$, Apr. 1896, *Donn. Sm.*, n. 6751 Pl. cit.—Atirro, Prov. Cartago, C. R., alt. 600^{m}, Apr. 1896, *Donn. Sm.*, n. 6753 Pl. cit.—Sub Sassafrideo (Ocotea) Veraguensi Meissn. distributa.—Incolis *Quisará*.

Obs. Species e pulcherrimis inter *O. Veraguensem et O. dendrodaphnem* intermedia huic propius accedens. Sed folia et textura et magnitudine nec non inflorescentia pluriflora optime paniculata, &c., plane differt.

Trema enantiophylla Donn. Sm.—Folia opposita oblongo-ovata basi rotundata interdum retusa, in ramis floriferis ovato-elliptica acute elongata basi acutiuscula, stipulis in unam intra-

petiolarem connatis, petiolis linea interpetiolari conjunctis. Cymulae in utraque axilla geminae, floribus dioicis. Perianthii segmenta imbricata. Floris masculini ovarium rudimentarium evolutum.

Frutex 4–6^{m} altus, ramis cavis medullosis glabrescentibus rubiginosis verrucosis, novellis pubescentibus. Folia majora 14–16^{cm} longa 8–10^{cm} lata, folia cymulas fulcientia 9–12^{cm} longa 3.5–5^{cm} lata, supra pilis bulbosis scabra subtus glabrescentia tri- vel tripli-nervia, nervis lateralibus utrinque 3–5 et basilaribus angulo acuto alte ascendentibus, petiolis pubescentibus 1.5–5^{cm} longis, stipulis lineari-triangularibus 3–6^{mm} longis. Cymulae pubescentes multiflorae, masculinae 20–25^{mm} longae, femininae 15–18^{mm} longae, pedicellis quam flores brevioribus basi bracteatis, floribus 5-meris. Floris ♂ perianthium 2.5^{mm} altum usque ad basin paene partitum, segmentis erecto-patentibus oblongo-ellipticis obtusis intus glabris, filamentis glabris perianthio paulo brevioribus jam in alabastro erectis, antheris subversatilibus, disco piloso, ovarii rudimento 1^{mm} longo stylo bifido rubescente apiculato. Floris ♀ perianthium minutum campanulare, lobis brevibus ovalibus, staminodiis 0, ovario semi-incluso subobovato 2^{mm} alto leviter compresso, stylo usque ad basin in ramos 2 ovario longiores totos stigmatosos diviso, ovulo pendulo. Fructus mihi non visus.—Species phyllotaxi et stipulis in Tribu *Celtidiae* abnormis Pileam mentitur. Num sit genus novum?

Secus flumen prope Estrella, Prov. Cartago, Cost., alt. 1800^{m}, Mart. 1888, *Juan J. Cooper*, n. 5949 Pl. Guat. &c., qu. ed. Donn. Sm.—Ad ripas Río Pedregoso, El Copey, Cost., alt. 1800^{m}, Febr. 1898, *Ad. Tonduz*, n. 7517^{B} Pl. Guat. &c., qu. ed. Donn. Sm. (n. 11734 herb. nat. Cost.).

Costus splendens Donn. Sm. et Tuerckheim.—Folia glabra petiolata maxima lanceolata e medio utrinque angustata, infima obovato-elliptica. Bracteae inferiores foliaceo-appendiculatae, florales optime ovales floribus maximis bis superatae. Calyx campanulatus quarta parte triangulari-dentatus. Corolla aurea, lobis obtusis. Labellum elongato-obovatum corollam triente superans 3-lobatum, lobis lateralibus sub-quadratis violaceo-purpureo-fasciatis, intermedio in lacinias 3 plus minus angustas recurvas aureas usque ad basin fere partito. Stamen oblongo-ellipticum, apice longe acuteque dentata inflexa.

Caulis biorgyalis et ultra circa 4^{cm} crassus, internodiis plerumque 4–6^{cm} longis, vaginis fere glabris, ocreis pilosis subtruncatis 1^{cm} altis. Folia usque ad 4–5^{dm} longa 12–13^{cm} lata sursum acute attenuata basi petiolo vix latiora, infima 32^{cm} longa 15^{cm} lata, subtus purpurascentia vel denique laete vire-

scentia, petiolis 14^{mm} longis basi dilatata 12^{mm} latis. Spica strobiliformis virescens bracteis 3–4 foliaceis $13–25^{cm}$ longis fulta, bracteis floralibus extus pubescentibus intus vinosis 5^{cm} longis 2.5^{cm} latis apice rotundatis, bracteola lineari 28^{mm} longa pubescente, floribus generis adhuc maximis circa 1^{dm} longis. Calyx pubescens $10–12^{mm}$ altus. Corolla glabra 6.5^{cm} longa, tubo 2.5^{cm} longo, segmentis obovato-ellipticis. Labelli lobi circa $20–25^{mm}$ longi, postici inaequales $22–25^{mm}$ lati margine erosi, laciniae anticae lineares vel oblanceolate $2–5^{mm}$ latae. Stamen 3^{cm} longum 13^{mm} latum ultra loculos 12^{mm} longos 17^{mm} productum. Stigma cano-pubescens semiorbiculare 4^{mm} latum, appendice vix breviore ovali bifido. Ovarium dense pilosum late cylindricum 11^{mm} longum.— Foliorum florumque magnitudine, et horum fabrica insignis.

Guatemala, alt. 350^{m}, Jul. 1901, *von Tuerckheim, n. 8015* Pl. Guat. &c., qu. ed. Donn. Sm.

DONNELLIA C. B. Clarke, nov. gen. *Commelinacearum.*—Capsula trivalvis, loculis monospermis; caetera Tradescantiae.

Donnellia grandiflora C. B. Clarke (sp. unica).—*Callisia grandiflora* Donn. Sm. in Bot. Gaz. **31**: 125. 1901.

This species cannot remain in *Callisia*, to which genus Donnell Smith has from the capsule referred it; as he observes, the stamens and the habit are those of *Tradescantia* Sect. *Descantaria*. We may either arrange the plant as a new subgenus *Donnellia* of *Tradescantia*, or call it DONNELLIA nov. gen., as here proposed. On the suggestion of Captain Donnell Smith, I may here give reasons for this course.

In my monograph of the Commelinaceae (DC. Monogr., Phan. III) no attempt is made to deal with the genera "logically;" the same characters, which in the American genera (*Tradescantia* and its allies) constitute genera, only constitute subgenera in *Commelina* and *Aneilema*. The main reason for this course (*i. e.*, following my predecessors), was to avoid the introduction of new names, and in particular of a disputed synonymy; and Bentham has here followed me; convenience has been preferred to any logical system.

A concrete instance may make this more quickly clear. The two subgenera of *Commelina* are absolutely distinguished (as *cf.* Bentham), and I might have taken up *Monoon* and *Didymoon* as genera (in order to make the arrangement consistent with that of the American group); in this case *Commelina nudiflora* L. would have become *Didymoon nudiflorum* C. B. Clarke, and *Commelina Virginica* L. would have become *Monoon Virginicum* C. B. Clarke. We should then have had two names current for each species; for many botanists would prefer to keep only one genus. But this would have been only a trifling inconvenience. A school of modern botanists, who believe in "laws," hold that the Linnean name *Commelina* must be retained for *something*, must not be sunk altogether. Then would arise the insoluble

problem whether the "type" of the Linnean genus *Commelina* was *some* species of *Didymoon* or *some* species of *Monoon*. Then there would be a question whether he had a type; or, if not, which was the *first* species he regarded as a *Commelina*. We should thus have had one set of botanists adopting the two genera *Commelina* and *Monoon*, another set those of *Didymoon* and *Commelina*, with two new names for each of the ninety species of *Commelina*. The case of DONNELLIA differs; treating it as a genus alters the name of no other existing species.

EXPLANATION OF PLATE XI.—FIG. 1, habit.—FIG. 2, cyme in fruit.—FIG. 3, flower.—FIG. 4, sepal.—FIG. 5, petal.—FIG. 6, perfect stamen.—FIG. 7, imperfect stamen.—FIG. 8, pistil.—FIG. 9, capsule.—FIG. 10, cross section of capsule.—FIG. 11, anterior and posterior views of seed.—*Figs. 1* and *2* are natural size; the others are variously enlarged.

Polypodium Alfari Donn. Sm. (§ EUPOLYPODIUM).—Frons parva pendula glabra pinnata linearis deorsum paulatim attenuata, pinnis utrinque 15–35 adnatis contiguis triangularibus vel e basi triangulari linearibus integris margine superiore ad basin dilatato angulo recto patentibus, inferiore decurrentibus, venis simplicibus paucis brevissimis in pinnarum dimidia parte exteriore nullis, soris 1–6 costae approximatis.

Stipites fasciculati filiforms arcuati castanei inferne pilis patentibus vestiti 1.5–2.5^{cm} longi. Frons membranacea 10–20^{cm} longa 1.5–4^{cm} lata, rhachi ebenea. Pinnae distinctae alternae medio 2–3^{mm} latae, inferiores laxiores, infimae ad alas cuneatas reductae, costa ebenea infra apicem evanescente, vena basali superiore ceteris longiore obsolete sorifera, soris majusculis rotundis, extimis ad costam subimpositis, paraphysibus nullis.—*P. capillari* Desv. proximum.—Oculatissimi repertoris in honorem dicavi.

In truncis arborum, Sierra Alta de Navarro, Prov. Cartago, Cost., alt. 2000^{m}, Maj. 1901, *Anastasio Alfaro*, n. 8063 Pl. Guat. &c., qu. ed. Donn. Sm.

BALTIMORE, MD.

C. E. Faxon, del. B. Meisel, lith. Boston.

OURATEA TUERCKHEIMII, Donn. Sm.

C. E. Faxon, del.

B. Meisel, lith. Boston

DONNELLIA GRANDIFLORA, C. B. Clarke.

THE RHEOTROPISM OF ROOTS.

FREDERICK C. NEWCOMBE.

(WITH FIFTEEN FIGURES)

[*Continued from p. 198.*]

II. VELOCITIES EFFICIENT IN THE FORMATION OF CURVES.

IN my published abstract,[1] already referred to, it was stated that definite relations exist between the velocity of flow and the response of the root. Juel[2] paid some attention to the same subject, finding that *Vicia sativa* grew generally with a negative curve, or straight, in velocities above 1800^{cm} per minute; while from that rate down to 1.8^{cm} per minute the response was generally a positive curve. Similarly with *Zea mays* (the variety is not given), the same author found devious behavior in a velocity of 3000^{cm} per minute, but positive curves in a velocity of 1200^{mc} per minute; in velocities of 66^{cm} to 18^{cm} per minute, he found 67 per cent. curved positively; while in velocities of 4.8^{cm} to 1.8^{cm} per minute, less than one-half the roots bent positively. It is clear, therefore, that in a velocity above 1800^{cm} per minute, the primary roots in both species named grow either straight or with a negative bend. As Juel points out, this does not necessarily mean that the roots are either insensitive or negatively rheotropic. They are probably bent negatively or held vertical by the mechanical push of the water. On the other hand, the lower limit of a stimulating current seems to have been approximated for *Zea mays*, but not for *Vicia sativa*, at the rate of 2^{cm} per minute.

My own experiments to determine the limiting velocities inducing response have been carried on with several plants, but

[1] Rheotropism and the relation of response to a stimulus. BOT. GAZ. **22**: 242. 1896; Proc. Amer. Ass. Adv. Sci. 1896.

[2] JUEL: Untersuchungen über den Rheotropismus der Wurzeln. Jahrb. Wiss. Bot. **34**: 507. 1900.

more extensively with *Zea mays* (popcorn), *Brassica alba*, and *Raphanus sativus*. While the general results could be given in a few words, yet, to afford the reader opportunity to judge the evidence, the following tables are given.

TABLE I.

EXPERIMENTS WITH ZEA MAYS (popcorn). Temperature in air 24°.

No. of experiment and revolutions per minute	Flow per minute	After 9¾ hours	After 18 hours
I 8 seedlings × 40	2500 to 500cm	8 roots = 0°	8 roots = 0°
II 9 seedlings × 26	1630 to 1300cm 1140 to 325	3 roots = 0° 6 roots = +15° to 40°	3 roots = 0° 6 roots = 0
III 8 seedlings × 16	1000cm 900 800 700 600 500 400 300	1 root = 0° 1 root = 0 1 root = 0 1 root = +10 1 root = +20 1 root = +20 1 root = +30 1 root = +40	1 root = −90° 1 root = −45 1 root = 0 1 root = +10 1 root = +25 1 root = +45 1 root = +60 1 root = +90
IV 9 seedlings × 2	125cm 113 100 88 75 62 50 38 25	1 root = +40° 1 root = +45 1 root = +45 1 root = +35 1 root = +40 1 root = +45 1 root = +45 1 root = +45 1 root = +45	1 root = +80° 1 root = +80 1 root = +45 1 root = +80 1 root = +60 1 root = +45 1 root = +50 1 root = +60 1 root = +50

The results recorded in the foregoing table were all obtained with seedlings of the same planting; the experiments were carried on at the same time, at the same temperature, and in the same room. The external conditions, therefore, were as nearly alike as possible.

An examination of my notes on experiments performed at various times during the past three years shows that *Avena sativa* has varied in its response according to the velocity of the flow. Unfortunately, the experiments not being made for the purpose of determining the effect of various velocities, the notes

were not taken in sufficient detail to show more than very general relations. The results are these:

TABLE II.

EXPERIMENTS WITH AVENA SATIVA. Temperature in air $22°$ to $25°$; period for each velocity from 10 to 17 hours, except in the case of 15 roots, where it was 30 hours.

Total no. of roots	Flow per minute	Percentages of curvatures
96	25 to 100^{cm}	$46\% = +$, $51\% = 0$, $1\% = -$
57	100 to 300	$81 = +$, $14 = 0$, $5 = -$
58	300 to 2000	$40 = +$, $30 = 0$, $30 = -$

From this table it is evident that streams with a velocity below 100^{cm} per minute do not bring responses in the majority of individuals; and that velocities of 2000^{cm} and below give many negative curves, these probably being merely mechanical. It is quite probable that velocities above 300^{cm} per minute would give a majority of positive responses, but my notes do not set the approximate upper limit.

The tests with *Brassica alba* show practically the same result as with *Avena sativa*. A velocity above 1000^{cm} per minute will give, so far as my test goes, only vertical and negatively bent roots, while a velocity between 600^{cm} and 1000^{cm} per minute will not bring a positive response in one-third of the roots.

TABLE III.

EXPERIMENTS WITH BRASSICA ALBA, to show upper limit of speed calling forth a response.

Total no. of seedlings	Temperature in air	Period	Flow per minute	Percentage of curvatures
62	$22°$ to $24°$	15 to 24 hours	50 to 500^{cm}	$87\% = +$, $13\% = 0°$, $0\% = -$
32	22 to 23	14 to 24	600 to 1000	$28 = +$, $50 = 0$, $22 = -$
8	23	14	1000 to 2000	$0 = +$, $50 = 0$, $50 = -$

The table fails to show the various angles assumed by the roots in various velocities. In the rates between 100^{cm} and 500^{cm} per minute, the angle was in more than half the roots between $60°$ and $90°$. In 56 seedlings tested in a velocity below 100^{cm} per minute, the angle attained averaged less than $40°$. In

velocities above 600^{cm} per minute, the angle was less than in the lower rate.

The lowest speed to which any of the roots will respond with well-marked curves has been determined in another series of experiments. The same general method was used as before, except that a klinostat gave the revolution, and no seedlings were set nearer than 3^{cm} to the center of the dish. The seedlings were thus suspended across the diameter of the basin in four groups, two being in the outer circular channel 45^{mm} in radial width, and two being in the inner channel 35^{mm} wide, there being an unoccupied central portion of water 55^{mm} in diameter. The innermost roots that were 3^{cm} from the center were therefore within 5^{mm} of the inner glass wall, and hence it may be assumed that the friction of the water on the glass wall would maintain there a water current with fairly constant direction, even in this slow movement.

In the following table the roots are grouped in two classes—those in the outer channel of the revolving basin where there was a velocity of 2.36^{cm} to 4^{cm} per minute, and those in the inner channel where the velocity was 1.18^{cm} per minute to 2^{cm} per minute.

TABLE IV.

EXPERIMENTS WITH BRASSICA ALBA, to show the lower limit of speed calling forth a response.

Experiments	Velocities = 1.18^{cm} to 2^{cm} per min.						Velocities = 2.30^{cm} to 4^{cm} per min.					
	No. of seedlings	% +	% o	% –	Average size of + angles	Extremes of + angles	No. of seedlings	% +	% o	% –	Average size of + angles	Extremes of + angles
I. 22° C., 23 hrs., × 1 in 16 min.	4 = + 3 = o°	57	43	o	24°	10° to 45°	8 = + 1 = o°	89	11	o	36°	10° to 45°
II. 22° C., 18 hrs., × 1 in 16 min.	4 = + 3 = o° 5 = –	33	25	42	29°	15° to 45°	14 = + 3 = o°	82	18	o	37.5°	10° to 45°
Total	8 = + 6 = o 5 = –	42	32	26	26°	10° to 45°	22 = + 4 = o°	85	15	o	37°	10° to 45°

The foregoing table does not tell the whole story. The roots in the velocities above 2^{cm} per minute had the characteristic appearance of rheotropic responses, the apical part of the root being bent in a curve. The roots in velocities below 2^{cm} per minute showed mere *inclinations* and not curves. Moreover, the bent roots in the higher velocity were in 80 per cent. curved only in a plane parallel with the current, while nearly all the bent roots in the lower velocity were curved either in planes oblique to the direction of the current, or they grew in two or more planes at various angles with one another. In other words, the *velocities below 2^{cm} per minute ceased to control the direction of growth.*

The fact last mentioned is further emphasized by the behavior of the roots of *Brassica alba* in basins of water revolving once in 24 minutes. With such a speed as this, the velocity in the outer channel of the basin extends from 2.50^{cm} to 1.80^{cm} per minute, and in the inner channel from 1.50^{cm} to 0.78^{cm} per minute. The behavior of the roots was about the same in both channels. Seventy-eight roots were used, the temperature being maintained constantly at 22° in air, and the period being 9 hours, 15 hours, 24 hours, and 28 hours in four experiments. Twenty-two roots inclined against the stream, fifteen with the stream, and forty-one roots were neutral. This gives 28 per cent. positive, 19 per cent. negative, and 53 per cent. neutral. But it would be unfair to regard these proportions as of much moment. Rather should it be said that the lower limit of velocity effecting positive responses on the part of these roots has been passed. It cannot be said, however, that the stream is wholly without influence on the direction of growth. Two-thirds of the mustard roots in velocities below 2^{cm} per minute deviated from the vertical direction in their growth. For purposes of summarizing the results given above, all roots bent from the vertical plane in which the seedlings were suspended were counted as either positive or negative, and all roots remaining in this plane were counted as neutral; but many of the roots counted as positive or negative were also oblique to the direc-

tion of the current, and many counted as neutral deviated from a straight course. That this very irregular direction of growth in streams of low speed is due to the movement of water is made known from the fact that these seedlings produce very straight roots in still water. In a control test, fifteen seedlings suspended with their roots in still water grew straight. It seems to be demonstrated, therefore, that currents of water with a velocity less than 2^{cm} per minute are not able to call forth a positive response in the primary root of *Brassica alba.*

The results obtained in attempting to determine the minimum, optimum, and maximum velocities for inducing a rheotropic response in *Raphanus sativus* show that this plant agrees very closely in these respects with *Brassica alba.* Since these results can be most briefly given in tabular form, we will again resort to that method of presentation.

TABLE V.

EXPERIMENTS WITH RAPHANUS SATIVUS, showing relation of response to velocity. Period, 8 to 24 hours, the record being made when the most curves showed in each experiment.

Total seedlings	Temperature in air	Flow per minute	Percentage of curvatures
36	22 to 24°	25 to 100^{cm}	72 % = + 28 % = 0 0 % = −
117	22 to 24	50 to 500	93 = + 3.5 = 0 3.5 = −
24	23	600 to 1000	12.5 = + 87.5 = 0 0 = −
10	22 to 23	1000 to 2000	0 = + 40 = 0 60 = −

From this table it appears that approximately one-fourth of the roots remain neutral in a velocity between 25^{cm} and 100^{cm} per minute, that the optimum speed lies between 50^{cm} and 500^{cm} per minute, and that velocities above 1000^{cm} per minute will not call forth a positive response. This table, however, is not a precise statement of the percentages of response, since some roots curved and straightened again before the final record was made. Such roots were very few in number, and it is not probable that the percentages would be changed more than one or two units if the more accurate record were made.

Not only is the largest number of positive curvatures obtained

in velocities between 50^{cm} and 500^{cm} per minute, but the largest angles also. The most of the curves in velocities below 50^{cm} per minute are less than 30°, while the greatest angles are attained in velocities between 200^{cm} and 500^{cm} per minute.

To determine the effect of a very slow current on the direction of growth of the roots of *Raphanus sativus*, three experiments have been carried out with the revolving water basin, divided as before into three concentric compartments, the roots being immersed in the two outer. The klinostats were adjusted to give one revolution in 32 minutes and one in 45 minutes, offering velocities ranging from 0.4^{cm} to 2^{cm} per minute. No difference in behavior of roots could be detected for the various velocities. The temperature of the air was held constantly at 23°; the period of two experiments was 22 hours, and the other 24 hours. Altogether seventy seedlings were used, giving thirty-four positive inclinations and three negative, while thirty-three roots grew straight.

In the first place, it may be said that the roots of Raphanus are not disturbed, as are those of Brassica, by the very slow currents of water. It will be recalled that two-thirds of the roots of the former grow irregularly in direction, in streams with a current below 2^{cm} per minute. The roots of Raphanus, which are designated above as neutral, pursued a vertical course downward.

In the second place, the fact should be emphasized that in these slow streams the character of the bend of the roots is different from that seen in the higher velocities. In the latter a positive curve is concave toward the stream; in the former the inclination against the stream is either convex toward the stream, or the inclination is in a straight line. In very weak currents, below 2^{cm} per minute, the apex of the root for 2^{mm} or 3^{mm} points vertically downward. The accompanying *fig. 8* will illustrate this difference. The angles attained by the roots of *Raphanus sativus* in these very low velocities ranged from 10° to 45° from the vertical.

Seeing that nearly all the bending roots of the radish are

turned against the stream, we must name the phenomenon positive rheotropism, even in velocities below 1^{cm} per minute. The case is different with the mustard. In that plant velocities below 2^{cm} per minute gave only 28 per cent. of obliquely positive inclinations to 19 per cent. of negative, and 53 per cent. of neutral roots. The difference between the number of positive and negative roots in the mustard is not so great that we may call the excess of 9 per cent. indicative of a positive response. With the radish, however, the roots bend only in a plane parallel with the stream, and thirty-four positive roots to three negative and thirty-three neutral require the verdict that approximately one-half the roots of *Raphanus sativus* are directed by a water stream with velocities ranging from 0.4^{cm} to 2^{cm} per minute, or even by a velocity of less than 1^{cm} per minute.

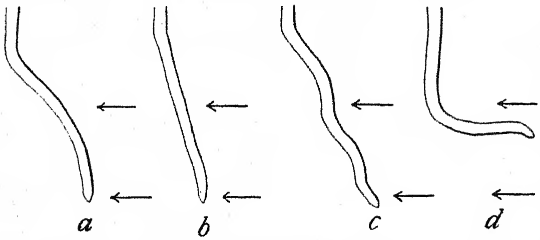

FIG. 8.— Four roots of *Raphanus sativus* after stimulation by the water current. Roots *a*, *b*, and *c* have been in streams with a flow of less than 2^{cm} per minute, while *d* has been in a stream of 200^{cm} per minute.

Helianthus annuus gives mostly positive responses in velocities from 100^{cm} to 600^{cm} per minute; while in one experiment with six seedlings, velocities from 600^{cm} to 2500^{cm} per minute, one root was positive, four negative, and three neutral. *Pisum sativum* in three experiments, with velocities from 500^{cm} to 1400^{cm} per minute, gave nine positive roots, sixteen negative, and nine neutral. From this we may infer that the higher velocities at least cause mechanically negative bends.

Vicia faba gives positive curves in a stronger stream than any other plant worked with. In one experiment, with velocities from 600^{cm} to 2500^{cm} per minute, eight roots bent positively, eight negatively, and three were neutral. In another experiment with six seedlings, two were neutral, while four were positive—one at 1000^{cm} velocity, one at 1500^{cm}, and two at 2000^{cm}.

This is the only plant that has not always given a negative bend in a velocity of 2000^{cm} per minute.

An examination of my notes on all experiments shows that, without having determined the optimum velocity precisely for any species, all of the plants I have worked with give the most constantly positive responses and attain the greatest angles in velocities between 100^{cm} and 500^{cm} per minute.

III. LATENT PERIOD AND AFTER-EFFECT.

A remarkable fact in the rheotropic response of roots is the extraordinarily long latent period. It is true that Berg[3] states that he obtained curves often within thirty minutes. But he gives neither the precise plants, nor temperature, nor velocity with which this result was obtained. When he used the reading microscope in an experiment with *Zea mays*, he found a minimum latent period of one hour. Juel (*l. c.*, p. 529), with *Vicia sativa*, temperature and velocity not given, believed he could detect initial curves in two hours.

My own results agree with those of Berg and Juel, but they have been extended over a larger number of plants, and have brought in also the relation of velocity of current to time of response. The following tables will show how these plants have behaved. Observations were made at the intervals recorded in the tables; and hence the curvatures recorded for any hour, except the first, may have begun between the time recorded and the preceding observation. Close attention failed to reveal any curvature earlier than eighty minutes. Observation was made with the unaided eye, and we may assume, therefore, that the reading microscope would have shown a shorter latent period than eighty minutes. Reference to *fig. 10*, page 275, will convince one that several of those curves must have begun at least ten to fifteen minutes earlier than the time recorded.

The mark "?" in the following table indicates that no observation was made at that time.

[3] Berg: Studien über Rhetropismus. Lunds Universit. Årsskr. 35^2: no. 6. 1899.

TABLE VI.

LATENT PERIOD FOR RAPHANUS SATIVUS.

Flow per minute	Temperature in air	Number seedlings	Behavior after 1½ hours	2 hours	2½ hours	3 hours	4 hours	4½ hours	6 hours	7 hours	10 hours	Total no. showing curves within 14 hours
25– 50cm	23°	3	o	o	o	o	o	o	o	o	o	o
60– 100	23	9	o	o	o	o	o	3+	3+	4+	4+	4+
125– 200	23	9	o	2+	2+	3+	3+	3+	5+	?	?	9+
225– 400	23	5	1+	2+	2+	2+	2+	3+	4+	?	?	5+
	26	10	1+	1+	1+	1+	5+	7+				7+
425– 750	23	12	8+	8+	8+	8+	8+	8+	8+	?	?	9+
	26	14	4+	4+	7+	7+	8+	8+				8+
775–1500	23	20	o	o	o	o	o	o	3+	3+	?	7+
1525–2500	23	5	o	o	o	o	o	o	o	o	?	1+

The following table shows the shortest latent period observed for several seedlings. It is certain that the latent period would not be shorter in a velocity either less or greater than that given for each plant, with the exception of that for *Brassica alba*. For this plant, experiment has not shown whether a quicker response would be found in a velocity greater than 250^{cm} per minute.

TABLE VII.

SHOWING SHORTEST LATENT PERIOD OBSERVED FOR SEVERAL PLANTS.

Plants	Optimum temperature for growth [4]	Temperature of air in experiment	Flow per minute	Latent period
Raphanus sativus	——	23°	200–400cm	1½ hours
Brassica alba	27.4°	23	200–250	2
Hordeum vulgare	28.7	23	100–225	2
Avena sativa	——	23	100–225	2½
Zea mays (popcorn)	33	24	200–400	3
Pisum sativum	25	23	200–600	3½
Helianthus annuus	31.5	23	150–300	3½
Vicia faba	26.6	25	225–675	6

Lathyrus odoratus responds so slowly that in a set of twenty seedlings in a favorable velocity of water, at a temperature of 20° to 23°, 24 hours elapsed before I was certain that the roots were responding; yet within the next 24 hours fourteen roots showed good rheotropic curves.

[4] These temperatures are taken from the tables in Sachs' *Text-book of Botany*, translated by Vines, 1882, p. 830, but are changed in two cases to accord with results obtained in my own work.

A comparison of the optimum temperature for growth with the temperature used in the experiments will indicate that the seedlings used would probably, in most cases, show in the optimum temperature a shorter latent period than that given.[5] We may suppose that by the aid of the reading microscope the latent period could be seen at the optimum temperature to end for *Raphanus sativus*, *Brassica alba*, and *Hordeum vulgare* in an hour. It is hardly to be supposed, however, that for *Pisum sativum*, *Lathyrus odoratus*, and *Vicia faba*, the latent period could be reduced to two hours. Compared with the latent period in geotropic response, the periods for rheotropism are extremely long. The roots of *Raphanus sativus* when laid horizontally in water, at a temperature of 26°, show to the unaided eye a geotropic bend in 15 minutes; those of *Pisum sativum*, similarly treated, show, at a temperature of 23°, a geotropic bend in 20 minutes. The latent period for rheotropism, therefore, is six times as long as that for geotropism. A rheotropic curve, however, is carried out in opposition to the geotropic tendency of the plant. No one has yet found the latent rheotropic period when gravitation is neutralized. A better comparison can be made with the heliotropic latent period, which is shown by the plant while still under the influence of gravitation.

If seedlings of *Brassica alba* and *Helianthus annuus* have their roots immersed in water in an air temperature of 23°, and are then exposed to one-sided illumination with strong, diffused light, their latent period will be found comparable to that in rheotropism. Four seedlings of *Brassica alba* were used, and the first negative bend perceptible to the naked eye came in 75 minutes. Within two hours of the beginning, all four roots had strong negative curves. The heliotropic curves in Helianthus did not appear until 2½ hours had elapsed; then only three roots out of five had responded.

Tables VI and VII also show the latent period in relation to the velocity of flow. In general, it may be said that for several

[5] CZAPEK (Jahrb. Wiss. Bot. **32**: 195) shows that the optimum temperature for growth gives the quickest geotropic response.

plants the latent period is shortest in velocities between 100^{cm} and 400^{cm} per minute. *Raphanus sativus* and *Vicia faba*, however, have shown their shortest latent period in velocities above 400^{cm} and below 750^{cm} per minute. The influence of velocity on the time of response is shown in a striking way by using the basin of water, revolving at a rate to give critical velocities in the radius, and by suspending a row of seedlings along the radius. From scores of such experiments, two may be selected here. In the first, the revolution was twice to the minute, giving along a radius velocities from 25^{cm} to 125^{cm} per minute. The temperature in water was 22°, and twelve seedlings of *Raphanus sativus* were employed. In two hours the three outermost seedlings had bent +; in three hours the three outermost were +; in four and one-half hours the six outermost were +; and in seven hours the seven outermost were +, while the remaining five nearer the center were all neutral. In the second selection, seedlings of *Brassica alba* were used. The temperature in water was 23°, the revolution 24 times to the minute, and the velocities ranged from 300^{cm} to 1500^{cm} per minute. After three hours the three roots nearest the center of the basin were +; after eight hours the six nearest the center were +; and after fifteen hours the eight nearest the center were +; while the fourteen outermost were all directed vertically downward and therefore to be called neutral.

The foregoing considerations have shown us that the time of response stands in definite relations to the velocity of current. We may at this point inquire whether the variation in the time of response in constant external conditions may be referred wholly to variation in the rate of growth. A seedling is usually regarded as so low an organism among organized beings, that one might expect a low degree of individualization, one might expect constant results in constant conditions of growth and environment. Could we not carry on our experiments in rheotropism quantitatively, and thereby look for constant latent periods and constant angles? The experience of every botanist is against such an assumption. Every one is familiar with the

fact that when several seedlings have their roots laid horizontally so as to carry out the geotropic curve, some roots bend at angles varying from those of the majority, indicating either an individualism in sensitiveness or in response. The rheotropic response shows like variation. In general, the most rapidly growing roots are the first to respond, but in nearly every experiment there are found roots varying their time of response from that of their fellows of equally rapid growth. This fact is illustrated by *figs. 9* and *10*. It is easy to see that root no. 5 has grown most and also curved most; but root no. 2 has grown less and bent more than no. 1, and no. 6 has grown less and bent more than no. 7. It is true that in these cases external conditions were not precisely similar, for the velocity of current for some of the roots was 675^{cm} and for others 725^{cm} per minute, disregarding the irregularities of current caused by the roots themselves. However, root no. 2 was in almost exactly the same theoretical rate of flow as no. 4, must have felt more of the irregularity of flow caused by the roots in front of it than did no. 4, and grew less than no. 4; yet it curved to a greater angle. On the other hand, many of these variations in physiological reaction could probably be reduced were care taken in selecting individuals whose past development and history were known to be similar.

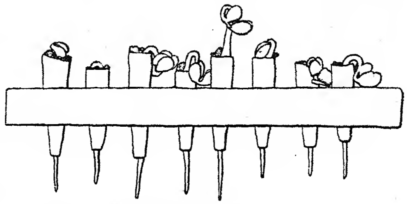

FIG. 9.—*Raphanus sativus*, tracing from a photograph. Seedlings ready for the experiment whose result is shown in *fig. 10*.

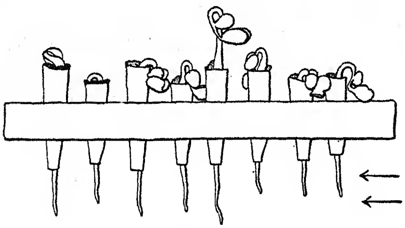

FIG. 10.—*Raphanus sativus*, traced from a photograph taken 1½ hours after placing the roots in a water stream with a temperature of 21°, and a velocity of 675^{cm} to 725^{cm} per minute. To show initial rheotropic curves.

The after-effect of the rheotropic stimulus is shorter than the

rheotropic latent period, both considered without the neutralization of the effect of gravitation. Roots of *Raphanus sativus* rheotropically curved have been seen to begin to straighten geotropically 20 minutes after the water stream was stopped, the temperature in air being 23°. Under similar conditions, except at an air temperature of 28°, the roots of *Zea mays* (*everta*) began to straighten geotropically in 40 minutes. On the other hand, two roots of *Vicia faba*, at a temperature of 25° in air, continued to bend rheotropically for an hour after the water stream was stopped.

From the foregoing results we may conclude that the rheotropic stimulus is in active competition with the geotropic stimulus, so that the operation of the latter is very quickly manifested when the former ceases to operate. One might have supposed the after-effect would have been considerably protracted, seeing that the latent period is so long. Such, however, is not the case. It remains an open question whether the rheotropic latent period would be greatly shortened were the opposing geotropism eliminated. The latent period in this response is no greater than that for traumatropism [6] and that for the clasping of some tendrils.[7]

IV. PERSISTENCE OF SENSITIVENESS.

The response of roots to a stream of water is continuous over a long period; and although there is some evidence to show that roots subjected to a rheotropic stimulus lose in great measure their geotropic sensitiveness, yet we may regard the direction taken by the roots growing in a stream of water as a resultant direction. This resultant direction forms a greater or less angle with the vertical according to the plant species, and according to the intensity of the rheotropic stimulus. This angle may reach 90° in *Fagopyrum esculentum*, *Raphanus sativus*, *Brassica alba*, and other plants, or it may average no more than 45° as in *Vicia faba*, *V. sativa*, *Pisum sativum*, and *Helianthus annuus*. A very weak

[6] SPALDING: On the traumatropic curvature of roots. Annals of Botany 8: 427.

[7] DARWIN: The movements and habits of climbing plants. London. 1875.

stimulus, such as that given by a water current of a few centimeters per minute, gives an average angle in *Brassica alba* and *Raphanus sativus* of perhaps 15°, while the most favorable stimulus brings a response averaging nearly 90°.

It might be thought that a root responding to the rheotropic stimulus by producing an angle of 45° to 90° from its direction of geotropic equilibrium would soon show signs of fatigue by the reduction of this assumed angle. Such behavior, however, on the part of the plant has not been observed, in cases where the stimulus is above a relatively low intensity and below a relatively high mechanical pressure. Thus, ten roots of *Zea mays* (*everta*), in velocities ranging from 50^{cm} to 100^{cm} per minute, all attained an angle of 45° in 11 hours, and maintained the same angle to the end of the experiment, 10.5 hours later. *Helianthus annuus*, with ten roots in water flowing 100^{cm} to 500^{cm} per minute, showed all roots retaining their angle of 90°, 33 hours after the beginning of the experiment, this angle having been attained by most of the roots 15 to 18 hours earlier. Ten seedlings of *Raphanus sativus* (variety Yellow Oval) all bent their roots positively in a velocity of 350^{cm} to 400^{cm} per minute, temperature of water 23°, in a period between twelve and eighteen hours, the exact time not being observed. The angles attained varied from 15° to 90°. Thirty-six hours after beginning the experiment all roots were still positive, and at angles of 30° to 90°. A set of seven seedlings of the Early Long Scarlet radish held their positive angles to the close of the experiment, twenty-nine hours after the angles first appeared.

If the current is very weak many instances have been observed in which a root straightens into its vertical position after an incipient rheotropic curve. Four roots of *Avena sativa* growing in constant current velocities ranging from 50^{cm} to 100^{cm} per minute became positively rheotropic within the first 3¾ hours, but all straightened within the ensuing 1¼ hours. *Brassica alba* in one preparation in a revolving basin where the velocities for the roots ranged from 50^{cm} to 100^{cm} per minute showed six roots positive within three hours, but within the next hour four

of these straightened. *Raphanus sativus*, during the first three hours of an experiment in which twelve seedlings were placed with their roots dipping into water, the velocities at the various distances from the center of the basin ranging from 50^{cm} to 100^{cm} per minute, and the water temperature being 22°, gave rheotropic responses in the three outermost roots. These roots after the lapse of four hours were seen to be straightening. Within the first seven hours of the experiment seven of the twelve roots bent positively, but after seven hours more, all twelve roots, except two tardily straightening ones, were in the vertical position, except for the fixed portions of the rheotropic curves.

Analyzing these results, it would seem that the matter can be thus stated: (1) a rheotropic curve in response to a weak stimulus will, sooner or later, be overcome by the response to gravitation, so that only the geotropic response is evident; (2) a stronger rheotropic stimulus acting at the same time with the normal geotropic stimulus may produce a curve giving a deviation of less than 90° from the vertical, this direction being regarded as a resultant of the water current stimulus and the gravitation stimulus; (3) with highly sensitive roots and a suitable rheotropic stimulus, an angle of 90° from the vertical may be attained, so that the geotropic response of the plant is wholly overcome by the rheotropic, except for the geotropic counter-curve which will be discussed later.

The overcoming of the response to one stimulus by that to another is well illustrated also in the horizontal position taken by stems in response to horizontally directed rays of light, where heliotropism apparently vanquishes geotropism.

V. THE GEOTROPIC COUNTER-CURVE.

One who studies the rheotropic behavior of roots soon notices that when a root has acquired an angle of great deviation from the vertical, the apical 2^{mm} of the root are bent downward, thus forming with the vertical a smaller angle than the part of the root farther back. If, for example, there is a rheotropic curve of 60°, the apex of the root will often show a down-

ward dip of 5° to 40°. This appearance is well illustrated in *fig. 11*.

Both Berg (p. 27) and Juel (p. 529) have discussed this phenomenon, but neither, to my mind, in a very satisfactory manner. The former suggests that the apical 2^{mm} of the root may not be sensitive to the water stream stimulus, and hence this part does not take the direction of the growing zone, which Berg believes to be sensitive. The objection to the argument of Berg lies in the fact that it is not a question of sensitiveness but a question of response. The receptive tissue and the responsive tissue may be, we know, quite widely separated in various irritable phenomena. Juel explains the S-shaped curve formed by the rheotropic curve and the geotropic counter-curve as resulting from the competition of rheotropism and geotropism, the former being the stronger in the proximal part of the growing zone, and the latter being the stronger in the distal 2^{mm}.

Before proceeding with the discussion of the S-shaped curve, it may be well to state that it is not peculiar to rheotropism, but is seen also in heliotropism. If seedlings of *Brassica alba* be set up in the usual way with one-sided illumination, I have found when the heliotropic curve reaches or surpasses 45°, that the apical 2^{mm} show a geotropic counter-curve like that seen in rheotropism. If now, we take into account the experiments of Czapek[8] and Němec[9] showing that geotropic sensitiveness is most likely confined to the apical 1.5^{mm} to 2^{mm} of the root, and the experiments of Czapek[10] showing that roots receive their strongest geotropic stimulus when at an angle of 135° above their vertically downward position, and that the effect of the stimulus diminishes constantly with the reduction of this angle, we can readily see that the geotropic downward dip of a rheotropically curved root diminishes greatly the strength of the

[8] CZAPEK: Untersuchungen über Geotropismus. Jahrb. Wiss. Bot. **27**: 243; **35**: 313.

[9] NĚMEC: Ueber die Wahrnehmung des Schwerkraftreizes bei den Pflanzen. Jahrb. Wiss. Bot. **36**: 78.

[10] CZAPEK: Jahrb. Wiss. Bot. **27**: 283.

geotropic stimulus, and thus gives a greater opportunity for the operation of rheotropism. When a root is displaced out of its position of geotropic equilibrium, the angle of ensuing geotropic curvature has been observed by many to begin, according to the diameter of the root, 2^{mm} to 3^{mm} back from the apex. Roots, such as I have used for the most part, are 1.25^{mm} or less in diameter. In these, the geotropic angle is at first about 2^{mm} from the apex; subsequently the curve extends backward, and includes several more proximal millimeters. We may follow the formation of the S-shaped curve thus: The rheotropic curve begins in *Zea mays*, according to Berg, in the $3d^{mm}$ from the apex; and according to Juel in the $3d^{mm}$ of *Vicia sativa*. I have frequently seen it originate in the $2d^{mm}$ of both *Brassica alba* and *Raphanus sativus*, though in these plants it is often first seen in the $3d^{mm}$. Berg's, Juel's, and my own observations agree in noting that the counter-curve generally does not appear till the rheotropic curve has reached an angle approximating $45°$. In one set of eight rheotropically curving roots of *Raphanus sativus*, seven had bent to $45°$ or over, and only one of these showed the dip of the tip. All these observations show that the tip of the root, even the apical 2^{mm}, may take a rheotropic curve. The part of the root farther back begins to curve a little later, and a portion removed as far as 11^{mm} from the apex, may, in *Zea mays*, according to Berg, participate in the rheotropic response. As the rheotropic angle increases, the sensitive apex of the root comes more and more into positions of increasing gravitation stimulus, till finally geotropism overcomes rheotropism, and the geotropic dip begins to appear. As soon, however, as the tip declines, the gravitation stimulus is less strongly felt and the rheotropic angle may now increase. This increase, however, is accomplished by farther bending several millimeters distant from the apex, the tip declining geotropically as the part behind it is lifted rheotropically. This behavior, after the S-curve begins to be formed, really implies a localization of the geotropic response and of the rheotropic response in different parts of the root. This fact is well worthy of special note, for by such initial geotropic curve

the root is enabled to attain to a considerably greater rheotropic and heliotropic angle. The continuance of this behavior brings about a constant straightening of the geotropic curve in its proximal part and a constant re-formation of the geotropic curve in its distal part, giving in a root of *Raphanus sativus* that has been in its rheotropic and geotropic equilibrium for some hours, 2^{mm} to 3^{mm} of the apex dipping to an angle of 45° to 15° from the vertical, back of this apex a straight piece from several to many millimeters in length, generally lying at an angle of 45° to 90° above the vertically downward position, and lastly the rheotropic angle in the form of a more or less open arc connecting the rheotropically growing piece of the root with the older vertical part. *Fig. 11*, drawn from a root of *Lupinus albus*, illustrates the features just described.

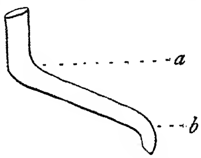

FIG. 11.— Root of *Lupinus albus*, showing (*a*) rheotropic curve and (*b*) geotropic counter-curve.

The rheotropic curve at the beginning may be quite like the geotropic curve of a root, but after some hours it will be noted

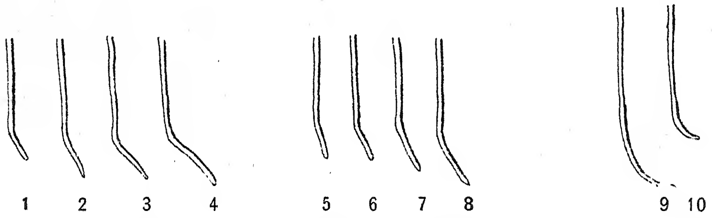

FIG. 12.— Numbers *1* to *4* are tracings of the rheotropic curves of a single seedling of *Raphanus sativus*, during the period of five hours. Numbers *5* to *8* are tracings of another root made at the same time. Numbers *9* and *10* show the geotropic curves of two roots of *Raphanus sativus*. The difference in the character of the rheotropic and the geotropic curves is apparent to the eye.

that the increase of the rheotropic curve is taking place by a bending farther back from the tip than occurs in a geotropic curve. *Fig. 12*, nos. *1* to *8*, shows rheotropic curves of two roots of *Raphanus sativus*, all made at the same time from the same variety and the same planting of seed. The roots

were traced by laying them on ground glass under water, drawing on the ground glass with a lead pencil kept parallel with the roots, then transferring to paper by laying the paper over the ground glass set in a window. *Fig. 12*, nos. *9* and *10*, shows geotropic curves after the plants had been lying horizontally for four hours, with roots in water at a temperature of 23°. The rheotropic curves of *1* to *4* were made in velocities of water ranging from 100^{cm} to 400^{cm} per minute, temperature of water being 22°; and the curves of *5* to *8* were made in similar circumstances except that the velocities ranged from 150^{cm} to 600^{cm} per minute. The early rheotropic curve of 32° at 3^{mm} from the apex in no. *1* continued to increase by farther bending in the same tissue even when this had become 5^{mm} to 6^{mm} distant from the apex, till in no. *4* the angle had become 43°. So also in the roots numbered *5* to *8*, it is evident from the figures that the initial bending of 15° at 3^{mm} from the apex in *5* has in *8* increased to 32° by farther bending in the same tissue, though in the latter case the apex of the angle is 6^{mm} from the root-tip.

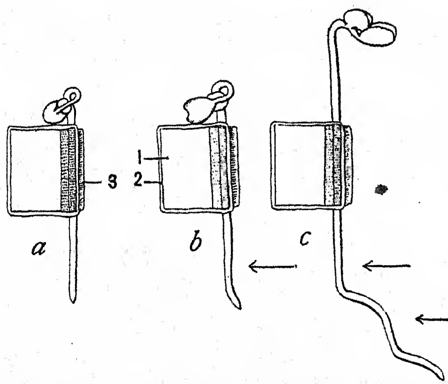

FIG. 13.—*Raphanus sativus.* Three stages of a single seedling illustrating the undulating course of the root; selected from a single preparation of 16 seedlings, 12 of which had similar curves; *a* shows the seedling before beginning the revolution of the basin of water; *b*, after three hours' revolution; *c*, after 21 hours' revolution. The number *1* represents the end of the supporting bar of wood; *2*, the rubber bands holding the two strips of blotting paper (*3*) against the bar of wood. The temperature was 23.5° in water.

A singular result worthy of note is the appearance in a root of several alternating curves of greater and of lesser angle, giving to the root an undulating course. This is well illustrated in *fig. 13*, where a root shows two greater angles and

two lesser. This phenomenon I have seen only in two conditions—in high temperatures when the growth was very rapid, and with a very weak stimulus, the latter illustrated in *fig. 8*, *c*. It may be explained in either of two ways. We may suppose that the root changes its sensitiveness or degree of response in successive periods of time; or we may suppose that the after-effect of the gravitation stimulus on the one hand, and of the rheotropic stimulus on the other alternately carries the bending root beyond the position of equilibrium, thus producing an oscillation back and forth over the position of equilibrium, the older part of the curving portion being fixed at the two extremes of position, thus producing the undulation observed. That a root may become non-responsive to a water stream after it has already given a rheotropic curve has been shown above. No observations have shown that such a root may in the same current of water show a second response. If, however, a root may regain its sensitiveness or its ability to respond after losing the same, we might expect the appearance of such an undulating course in growth as that just described.

[*To be concluded.*]

A DESCRIPTIVE LIST OF THE PLANTS COLLECTED BY DR. F. E. BLAISDELL AT NOME CITY, ALASKA.

ALICE EASTWOOD.

[*Concluded from p. 213*]

GENTIANACEAE.

133. GENTIANA FRIGIDA Haenke. Jacq. Coll. **2**: 13. Ledeb. Fl. Ross. **3**: 65. DC. Prodr. **9**: 111.—Stems erect, glabrous, 1–1.5^{dm} high: radical leaves linear, connate at base, 1-nerved, 3–6^{cm} long, 2–3^{mm} wide; cauline leaves broad, 1 or 2 pairs, broader and shorter: flowers terminal, 1-3, sessile or on short peduncles, subtended by a pair of leaves: calyx about half as long as the corolla, with the linear-lanceolate divisions shorter than the tube: corolla funnelform, about 4^{cm} long, whitish with greenish-purple dots, the lobes short and broad, sinuate, the plaits broad.

Specimens too young for fruit.

134. GENTIANA GLAUCA Pall. Fl. Ross. **2**: 104. *pl. 93, fig. 2.* 1784–88. Griseb. in Hook. Fl. Bor.-Am. **2**: 58. *pl. 147.*—Stems from slender running rootstocks, glabrous throughout, erect, generally with two pairs of leaves, 6–15^{cm} high, terminated by a few-flowered capitate cyme: leaves obovate to oval, 1–1.5^{cm} long, scabrous on the margins: flowers subtended by a pair of involucral leaves, sessile or on short pedicels: calyx campanulate, 7^{mm} long, with deltoid lobes 2^{mm} long, tapering to the base: corolla 15^{mm} long, acuminate at base, with broadly deltoid obtuse lobes 1.5^{mm} long, the membranous sinus between each either truncate or tipped with a very short lobe: stamens unevenly inserted: ovary on a stipe of almost its own length: capsule exserted beyond the corolla when ripe: seeds invested with a transparent cellular coat which is winged at 2, 3, or 4 angles.

Type locality: "Kamtschatka" ex Ledeb. Fl. Ross 3:66.

I am not at all sure that this is *G. glauca*. The foliage is apparently bright green, the filaments are uneven, and the lobes in the sinus of the corolla divisions scarcely apparent.

135. GENTIANA PROPINQUA Richards. App. Frankl. Journ. 734. 1823. Hook. Fl. Bor.-Am. 2:62. *pl. 150.*—Root apparently annual: main stem slender, angled, glabrous 5–12^{cm} high, with several more slender and shorter stems or branches from the axils of the radical leaves: leaves in a rosulate tuft at base, narrowly obovate, 1^{cm} long, 4^{mm} wide; cauline leaves ovate, sessile, scabrous on the margins, always with the long-peduncled flowers in their axils: peduncles 1–3^{cm} long, slightly winged especially under the flowers: calyx of two broad ovate-acuminate divisions 5^{mm} long and 2^{mm} broad, and two linear-lanceolate divisions half as broad, scabrous on the margins: divisions of the corolla entire, ovate-acuminate, as long as the swollen tube; glands at base of tube small: stamens inserted below the sinus, the reniform anthers exserted: capsule lanceolate in outline, sessile, 6^{mm} long: seeds oval, brown, 1^{mm} long, minutely papillate.

Type locality: "Cumberland house to Bear lake, and Bear lake river."

CAMPANULACEAE.

136. CAMPANULA LASIOCARPA Cham. Linnaea 4:39. 1829.—Stems 2–10^{cm} high, slender, sparingly leafy below, villous: radical leaves lanceolate, narrowed to a petiole, dentate with remote bristly teeth, usually curved; stem leaves linear with the marginal teeth longer: tube of calyx campanulate, half as long as the narrow, acuminate divisions, laciniate-dentate: corolla campanulate, blue, 15^{mm} long, 2^{cm} broad, shortly acuminate, 3-nerved, with broad nerves.

Type locality: "In collibus et montibus Unalascheae."

137. CAMPANULA UNIFLORA L. Sp. Pl. 163. 1753. Fl. Lapp. *pl. 9.*—Stems simple, 1-flowered: radical leaves spatulate to linear-oblanceolate, 5-15^{mm} long: cauline leaves distant, linear-acuminate: flowers small, dark blue: corolla about twice as long

as the subulate divisions of the calyx: tube and divisions of the latter cinereous with white hairs: capsule clavate, 3^{cm} long.

Type range: "in alpibus Lapponicis."

POLEMONIACEAE.

138. Polemonium acutiflorum Willd. ex Schult. Syst. 4:792. DC. Prodr. 9:318.—Stems erect from creeping scaly rootstocks, $2–4^{dm}$ high, glabrous except for the viscid pubescence of the inflorescence: leaves few, those from the root somewhat larger than the cauline leaves; leaflets 9–24, opposite or alternate, oblong-lanceolate to ovate, mucronate, $3–15^{mm}$ long, decurrent on the winged rachis; petioles generally shorter than the blades, winged, dilated and sheathing at base, the whole leaf $5–10^{cm}$ long; stem leaves few and scattered, similar to the radical leaves but smaller, with the petiole woolly-ciliate, especially at base: flowers in a narrow thyrsus or panicle with the peduncles 6^{mm} to 6^{cm} long; bracts usually trifoliate with linear divisions, sessile and clasping; bractlets lanceolate or scale-like, sometimes wanting: calyx campanulate, with the divisions about half the entire length, in flower 4^{mm}, becoming 10^{mm} in age; tube glandular-woolly, thin and membranous between the divisions; divisions of the calyx triangular-subulate, acute or callous-tipped, veiny: corolla rotate-campanulate, with tube very short and divisions obovate; these blue, often darker at base, obovate, acute or obtuse, with margin crisped or entire, ciliate, 12^{mm} long, 8^{mm} wide; tube with a hairy ring 3^{mm} from its base and tufted at the base of the filaments: filaments glabrous, about 8^{mm} long, one-third shorter than the corolla: style but little longer: capsule as long as or sometimes longer than the tube of the calyx: seeds brown, linear-oblong, 4^{mm} long, the body of the seed chestnut-brown with yellow-brown wings at each end.

Type locality: "in Americae borealis plaga occidentali (Pallas)."

In Ledebour *Flora Rossica* 3:84 this is given as a variety of *P. caeruleum* L. It was collected by Chamisso at Unalashka. Insula Sancti Georgi Promontorium Espenbergii. Sinus Eschscholzii. Insula Chamissonis. ex Linnea 6:551.

We have no specimens of this for comparison and all the descriptions are so meager as to be quite unsatisfactory; but it is certainly near this if not quite identical.

BORAGINACEAE.

139. **Mertensia Alaskana,** n. sp.—Stems erect, 2–4^{dm} high, leafy with erect leaves appressed to the lower stem, more spreading on the upper, ribbed, glabrous: lower cauline leaves oblong-lanceolate, acuminate, on broad margined petioles about the length of the blade, together 3–8^{cm}; upper leaves sessile, ovate-lanceolate, acuminate, 4–7^{cm} long, revolute, with prominent veins, strigose-pubescent on both surfaces, but more so on the lower, with the short appressed bristles minutely pustulate at base: panicle generally of 3 branches, the lower one solitary, the two upper dichotomous, 2-leaved at base and with a single flower on a deflexed pedicel in the fork; peduncles glabrate, 6–8^{cm} long, naked to the racemose or again panicled flowers; bracts 2, opposite, 15^{mm} long, lanceolate-attenuate; pedicels about 1^{cm} long, sparingly strigose-pubescent, spreading, erect or recurved: calyx divisions subulate, 2^{mm} long, glabrous on the outer surface, minutely hispid on the inner, with ciliate margins: tube of corolla 5^{mm} long, 3^{mm} broad; limb campanulate, 7^{mm} long, almost 1^{cm} in diameter; the rounded lobes 3^{mm} long, 4^{mm} wide; folds in the throat forming a yellow moniliform ring, those at the base of the tube fleshy or bladder-like: stamens on broad margined filaments inserted below the throat; the yellow, narrowly elliptical anthers almost 3^{mm} long, together with half the filament exserted from the throat but included in the limb: nutlets exceeding the sepals, pectinately rugose-tuberculate on the dorsal surface and margins, strongly keeled and rugose on the ventral, loosely investing the seed and firmly attached to the gynobase, very brittle; the scar of attachment near the base; the apices not connivent.

This is included by Dr. Gray under *M. paniculata* Don., Syn. Fl. 2 : 201. Specimens sent to Dr. E. L. Greene were identified by him as *M. strigosa*, Pittonia 4 : 88. It does not agree with the description of his plant and seems to me to be undescribed.

140. MYOSOTIS SYLVATICA ALPESTRIS Koch. — *M. alpestris* Schmidt, Lehm. Asper. 86. — Caudex branched, from woody rootstocks: stem leafy, simple below the panicle, 10–18^{cm} high, with loose hirsute pubescence: radical leaves oblong-lanceolate, tapering to petioles equaling or longer than the blades, together 2.5–6.5^{cm} long, 5–10^{mm} wide, hirsute and ciliate, obtuse; cauline leaves narrower, oblong, sessile, 1–3^{cm} long: peduncles slender, flowers at first close together, later becoming 3^{cm} apart; pedicels becoming twice as long as the calyx: sepals subulate, 2^{mm} long, white-hirsute: corolla blue, salverform, with tube equaling or surpassing the calyx; limb longer than the tube, with sub-orbicular lobes 2.5^{mm} broad; folds in the throat bilobed; appendages at base 10, globular: stamens inserted on short filaments below the folds; the yellow, elliptical anthers protruding from the throat: nutlets not all maturing, erect, very glossy, attached at the base; scar round; apices somewhat spreading; margined and somewhat keeled on the inner side near the apex.

The specimens at hand vary considerably in size.

141. OMPHALODES NANA Gray Syn. Fl. Suppl. 423. *Myosotis aretioides* Cham. Linnaea **4**: 443. 1829.— Low, depressed-cespitose, forming dense mats with tufted branches to the caudex: leaves sessile, imbricated, forming rosettes, densely white-villous, oblong-elliptical, about 3^{mm} long: peduncles immersed in the leaves, flowers as if sessile: calyx with oblong acute divisions extending to near the base, 1.5^{mm} long, surpassing the tube of the corolla: nutlets with a toothed or spinulose border on the back.

Type locality: "Ad sinum St. Laurentii mixtim cum precedente, melioraque specimina in insula Sancti Laurentii 1817 collegimus." Chamisso.

SCROPHULARIACEAE.

142. PEDICULARIS CAPITATA Adans. Mem. Soc. Nat. Mosc. **5**: 100.— Perennial from slender running roots: stems scapose or with 1 or 2 leaves below the inflorescence, pubescent with white-woolly hairs: radical leaves on long petioles, once to

twice the length of the blades; these pinnately divided with segments opposite or alternate, ovate, incisely lobed; stem leaves similar but on shorter petioles: flowers capitate; bracts sessile, with oblong, crenate divisions, surpassing the calyx: calyx woolly-pubescent, about as long as the tube of the corolla, enlarging somewhat in age: corolla about 3^{cm} long; lower lip erect, with the lobes not spreading, orbicular, crenulate, woolly-pubescent to the insertion of the stamens, gibbous below the throat; upper lip arching, truncate at tip, about 5^{mm} broad, apparently yellowish-white tinged with rose-color; tube 1^{cm} long: filaments villous at base, inserted 1.5^{mm} above the base, flat with a central rib; anthers purplish, the margins and sagittate bases white: ovary conical, with style 4^{cm} long; stigma capitate: capsule oblique at apex, beaked on one side, exserted from the calyx.

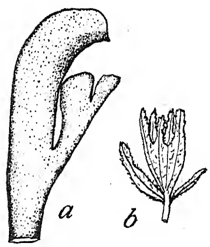

FIG. 6.— Pedicularis capitata. *a*, corolla; *b*, calyx. Nat. size.

143. PEDICULARIS sp.—This is closely related to the preceding, but as there is only one specimen and that not good, I hesitate to name it as a distinct species. The difference in the shape of the flowers can be seen from the figures. It differs from *P. capitata* in the shape of the bracts, calyx, corolla, and in the glabrous filaments.

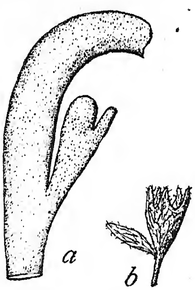

FIG. 7.—Pedicularis sp. *a*, corolla; *b*, calyx. Nat. size.

144. **Pedicularis hians,** n. sp.—Root slender, woody, branching 1^{cm} below the stem: stems 1–several, $10-15^{cm}$ high, purple, glabrous and shining below, becoming woolly-pubescent above, clothed at base with brown, imbricated, ovate scales; radical leaves on very slender petioles 2–3 times the length of the pinnatifid blades, glabrous with few very (2^{mm} long) dentate divisions; cauline leaves $2-2.5^{cm}$ long with broad, linear-lanceolate rhachis twice as broad as the deltoid, entire or dentate, tooth-like divisions which extend almost or quite to the base of the

leaf, glabrous except for a few woolly hairs: bracts similar to the cauline leaves, the lower ones surpassing the flowers: flowers capitate, becoming racemose-spicate, on short erect pedicels appressed to the stem: calyx of 5 divisions, the upper one keeled, the 2 lower with the notch between deeper than the others, the 2 side lobes tipped with a crenate-dentate apex, slightly woolly-pubescent: corolla purple with exserted tube, falcately curved galea with the tip blunt and a setaceously acuminate tooth below the apex; lower lip 3-lobed, with orbicular lobes, the middle one smallest, crenate on the margins; throat hairy within, the hairs extending to the tube below: filaments woolly at base and below the anthers; these reddish, tipped with white at the sagittate base: capsule oblique, lanceolate, twice as long as the calyx, cuspidate at apex; style and white tips of anthers exserted.

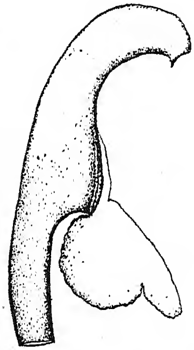

FIG. 8.—Pedicularis hians. × 2½.

This is near *P. Sudetica* Willd., but differs in the shape of the corolla and the form of the leaves.

145. PEDICULARIS HIRSUTA L. Sp. Pl. 609. 1753.—Stems rather stout, about 1.5^{dm} high, clothed at base with the sheathing brown petioles of former leaves: radical leaves with rhachis 1^{mm} broad, divisions numerous, linear, dentate, glabrous, entire leaf 5^{mm} wide, and together with the petiole 5–7^{cm} long; cauline leaves with much broader rhachis and divisions smaller, resembling the snout of a sword-fish, lanate at the dilated bases: inflorescence racemose-spicate, villous-lanate, with erect pedicels about equaling the calyx: calyx campanulate, dentate, ribbed, lanate at apex, 4^{mm} long: corolla with tube a little longer than the galea (8^{mm}), exserted from the calyx; galea about 5^{mm} long, erect, arched, obtuse at apex; lower lip with the lobes almost equal, the middle one concave, erosely crenate

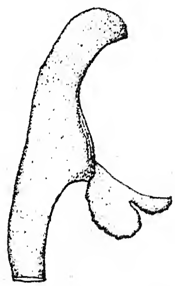

FIG. 9.—Pedicularis hirsuta. × 2½.

on the margin, glabrous within; stamens with 2 filaments glabrous and 2 woolly-pubescent; anthers white, blotched and dotted with brown on the middle: capsule twice as long as the calyx, beaked on one side.

Type range: "in Lapponiae Alpibus."

146. PEDICULARIS LANGSDORFFII Fisch. in Stev. Monogr. in Mem. Soc. Mosc. **6**: 49. *pl. 9. fig. 2.* excl. var. *b.*—Stems low, rather stout, 8–10^{cm} high, clothed at base with broad ovate scales: radical leaves with petioles equaling the blades, together 4–6^{cm} (generally there are some smaller and shorter leaves on very short petioles), pinnatifid with oblong-deltoid divisions, confluent, crenate-dentate near the apex; cauline leaves with the lobes deltoid and generally entire: flowers spicate, but on short appressed pedicels: calyx narrow, 1^{cm} long, 2–3^{mm} wide, conspicuously ribbed, with divisions unequal, linear, foliaceous, some or all crenate near the apex, 3–4^{mm} long: corolla with tube about equaling the galea, exserted from the calyx; galea curved but not falcate, obtuse at apex; lower lip with middle lobe much smaller than the other two: stamens with two filaments woolly and two glabrous: capsule not formed.

Type locality: "in Sibiria Arctica circa ostia Lenae." "Kamtschatka," ex Ledeb. Fl. Ross. **3**: 288.

147. PEDICULARIS LANATA Willd. ex Stev. l. c. 1823.—Similar to the preceding, but the leaves have the divisions more finely lobed and so appear more dissected, the spike is densely lanate and the flowers are smaller: calyx about 5^{mm} long, with obtuse entire divisions half the entire length: corolla with tube equaling the galea; lower lip prominently ridged on the upper surface.

The general form of these two species is the same, the filaments of the last being more densely woolly.

148. PEDICULARIS SUDETICA Willd. Sp. Pl. **3**: 209. no. 13.—Stems 1–several from the root, clothed at base with brown sheaths, glabrous to near the inflorescence, sparsely leaved: radical leaves on broad petioles, longer than the blades, pinnatifid, with divisions linear-oblong, incisely toothed, with white

cartilaginous teeth 3–4^{mm} long; cauline leaves similar but sessile: bracts like the leaves or simple with incised or crenate margins, linear in outline, longer than the calyx: flowers on short pedicels, crowded on a capitate spike that lengthens some with age, woolly-pubescent: calyx shorter than the tube of the corolla, with linear divisions 3^{mm} long, acute, about half as long as the purple, glabrous tube: corolla purple; lower lip with 3 orbicular spreading lobes, the middle one longest but narrowest, erose-crenulate; galea arching a little, longer than the lower lip, with 2 teeth at tip: filaments glabrous: capsule oblique at apex, beaked on one side, exserted from the calyx about 2^{mm}.

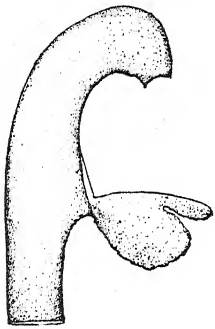

FIG. 10.— Pedicularis Sudetica. $\times 2\frac{1}{2}$.

Type range: "in montibus Sudetis inque Sibiria."

149. PEDICULARIS VERTICILLATA L. Sp. Pl. 608. 1753.—Stems several from a thick root, 10–15^{cm} high, reddish, woolly-pubescent, leafy with opposite or whorled leaves: leaves petioled, pinnately divided, the oblong divisions with white cartilaginous teeth: flowers purplish, in interrupted, bracteate, whorled spikes: calyx shorter than the tube of the corolla, woolly, veiny, dentate: corolla with galea erect, scarcely arched, with blunt tip, spreading from the 3-lobed lower lip which is longer and several times broader: capsule ovate-acuminate, 1^{cm} long, much exserted.

Type range: "in Sibiria, Helvetia, Austria."

150. VERONICA ALPINA L. Fl. Lapp. *pl. 9. fig. 4.* 1792.—Stems slender, with small, opposite, ovate leaves, entire or sparingly denticulate: flowers small, purplish-blue, in an oblong or capitate spike: fruit emarginate.

The woolly pubescence becomes glandular on the inflorescence and the upper part of the stem. It is apparently abundant.

In the figure referred to above, the stamens and style are exserted beyond the corolla, but in all the specimens at hand they are shorter than the corolla. It seems more like the variety figured in the Bot. Mag. *pl. 2975* under var. *Wormskioldii.*

SELAGINACEAE.

151. LAGOTIS GLAUCA J. Gaertn. Nov. Comm. Petrop. **14**: 533. 1770. *Gymnandra Stelleri* Ch. & Schl. (1827).— Leaves mostly radical, those on the stem bract-like: fruit 2-celled, as in the Scrophulariaceae, but each cell with but one seed: calyx spathe-like: corolla blue, tubular-bilabiate; upper lip entire, lower 2-cleft: stamens 2, inserted in the throat of the corolla, not equaling the style, which is capped with a capitate stigma.

Type localities: "in Siberia inter Lenam et Oceanum (Steller) nos in frigidissimis rupestris ad sinum St. Laurentii collegimus." Chamisso.

This rarely collected plant has the appearance of Synthyris.

LENTIBULARIACEAE.

152. **Pinguicula arctica**, n. sp.— Leaves rosulate, glabrous, apparently fleshy, broadly ovate, sessile, obtuse, 1–2^{cm} long, 5–8^{mm} wide: scape purple, glabrous below, glandular-pubescent above, 1-flowered, 7^{cm} high: calyx 2-lipped; upper lip of 3 deltoid divisions half as long as the lip, the sinus acute; lower lip narrower, with 3 shorter teeth and obtuse sinus one-third as long as the division: corolla purple, 11^{mm} long, hairy within, with club-shaped hairs that extend to the lobes of the upper lip; lobes 3, orbicular, 4^{mm} across; lower lip of 2 similar but shorter lobes; spur slender, tapering, 7^{mm} long: stamens 2, with filaments dilated at base, nearly 2^{mm} long, surmounted by capitate anthers: ovary orbicular, glabrous; stigma of 2 white broad plates, thin in texture.

This appears to be near *P. vulgaris*, but the corolla is of a different shape and hairy within, while the spur is longer.

RUBIACEAE.

153. GALIUM BOREALE L. Sp. Pl. 108. 1753.—This is found throughout the northern hemisphere. The leaves are in whorls of 2 to 4, the tiny white flowers in loose thyrsiform panicles, and the fruits densely hispid.

Type range: "in Europae borealis pratis."

CAPRIFOLIACEAE.

154. LINNAEA BOREALIS L. Sp. Pl. 631. 1753.—The beautiful twin-flower is found throughout the northern hemisphere at high latitudes and in the mountains at subalpine elevations.

Type range: "in Sueciae, Sibiriae, Helvetiae, Canadae sylvis antiquis, muscosis, sterilibus, umbrosis."

VALERIANACEAE.

155. VALERIANA CAPITATA Pall. Link. Jahrb. 1^3: 66. Ledeb. Ic. Fl. Ross. *pl. 346.*—Stems simple, $18–30^{cm}$ high: lowest stem leaves suborbicular, on broad connate-clasping petioles as long as the blade, together $1–2^{cm}$ long; second pair of leaves unequally and broadly ovate, 2.5^{cm} long, on similar petioles 5^{mm} long, obscurely denticulate; third pair ovate-acuminate, with narrow lanceolate-acuminate lobes at the sessile base, these lobes one-fifth the length of the main division; nodes hirsute: inflorescence capitate-glomerate; peduncles long, sometimes with two slender branches; involucral leaves of narrowly linear to almost filiform divisions; bracts of the cyme narrowly linear-subulate: corolla white tinged with rose, funnelform, $6–7^{mm}$ long, one lobe broader than the other three, tube slightly saccate at base: stamens 3, together with the 3-lobed styles exserted: akenes ovate, 3^{mm} long, 1-nerved on one side, 3-nerved on the other.

Type locality: "mont. sabinensibus."

COMPOSITAE.

156. ACHILLEA MILLEFOLIUM L. Sp. Pl. 899. 1753.—Stems erect, $1–3^{dm}$ high, simple or branched above: leaves bipinnatifid, with the segments pinnately-parted into fine setaceous divisions, lanceolate in outline, $4–9^{cm}$ long, $5–10^{mm}$ wide, the lower ones on short petioles dilated at base, the upper sessile: the entire plant white-villous, most densely so at the leaf axils: heads in a broad compound cyme, often with later branches below the main cluster; bracts of the involucre in 3 series, in successive ranks, the linear inner ones narrower and longer than the ovate outer ones, each with the midrib green, keeled, and the border brown

hyaline: rays white, oblong-orbicular, entire 3^{mm} long 2.5^{mm} wide.

Type range: "in Europae pascuis pratisque."

157. ANTENNARIA ALPINA Gaertn. Fruct. **2**:410. *pl. 167.* 1791.—Heads solitary, with campanulate involucre tomentose at base, above black-brown: involucral scales of the male plant obtuse, denticulate at apex, often emarginate; those of the female plant acuminate: upper leaves terminated by a scarious appendage, the lower mucronate.

This agrees perfectly with the description of Lessing in Linnaea **6**:221.

158. **Aster arcticus,** n. sp.—Stems low from a slender creeping rootstock, striate, villous below, becoming lanate under the solitary head, leafy, $1-1.5^{dm}$ high: lowest leaves linear-oblong to narrowly elliptical, sessile, mucronate; upper ones lanceolate, acuminate, short-petiolate, sharply serrate: pubescence on the lower surface rough, appressed; glabrous on the upper: head 2^{cm} in diameter; bracts of involucre equal, lanceolate-acuminate, purple-margined or the inner ones entirely purple, villous, 8^{mm} long, $1-2^{mm}$ wide: disk corollas purple, glabrous: stamens yellow: style with the appendages hairy at the tips: akenes white-hispid: pappus tawny or the outer purplish.

This is near *Aster prereginus* Pursh, none of the synonyms of which describe it. On sand bars of Nome river.

159. ARNICA OBTUSIFOLIA Less. Linnaea **6**:236. 1831.—Leaves clustered at the base, oblong, tapering to a broad base, callous denticulate and tipped with a callous point, 3-veined from base to apex, generally also with a shorter vein on each side near the margin, $3-5^{cm}$ long, $5-10^{mm}$ wide, glabrous except for the ciliate margins: heads solitary, terminating long penduncles, almost 2^{dm} high, woolly-pubescent: involucral bracts in 2 series, lanceolate, the outer purplish, broader than the green, inner ones 11^{mm} long: rays 10, 3-toothed at apex, ligulate, 15^{mm} long, $3-5^{mm}$ wide: stamens with black anthers: akenes glabrous: disk corollas with tube hairy and limb glabrous.

Type locality: Unalaschka."

160. ARTEMISIA NORVEGICA Fries, var. PACIFICA Gray Syn. Fl. N. Am. **1**: 371.—Stems erect, about 3^{dm} high, glabrous below, villous above: leaves pinnatifid with the divisions incised, the upper 3 confluent, the lowest smallest; petiole of basal leaves equaling the blade, clasping at base; cauline leaves sessile with simpler divisions: heads racemose-paniculate, on long slender peduncles, somewhat secund, nodding at summit: involucral bracts glabrous, dark green margined with brownish-purple, scarious and erose on the margins: disk flowers with perfect akenes.

While this does not agree exactly with the description of the above cited variety it seems best to leave it under that name.

161. ARTEMISIA TILESII Ledeb. Mem. Acad. St. Petersb. **6**: 568, ex Linnaea **6**: 214. 1831.—Stems erect, 3–4.5^{dm} high, striate, somewhat tomentose: leaves pinnately parted into 3–7 linear-attenuate divisions, the top one much the longest, densely white-tomentose on the lower surface, less so on the upper: bracts linear-attenuate, sometimes with 1 or 2 narrow divisions near the base: heads nodding on erect pedicels in a narrow spiciform thyrsus, more loosely flowered below and taking up half the length of the plant: bracts of the involucre with the middle part greenish, villous, the margin violet-brown, erose: corolla purple or yellow, with glandular tube.

162. CHRYSANTHEMUM INTEGRIFOLIUM Richards App. Frankl. Journ. ed. 2, p. 33. 1823. *Leucanthemum integrifolium* DC. Prodr. **6**: 46. 1837.—Stems low, scapose, terminated by a solitary head, 2.5^{cm} in diameter, white-villous, about 8^{cm} high: leaves rosulate, linear, obtuse, entire, 1-nerved, 1^{cm} long: involucral bracts green in the middle and hairy, brown-scarious and erose on the margins, acuminate, 4^{mm} long: rays white, ligulate, obtuse or emarginate at apex, 9^{mm} long, 2^{mm} broad: akenes small, glabrous, without pappus.

163. ERIGERON UNIFLORUS L. Sp. Pl. 864. 1753. Fl. Lapp. *pl. 9. fig. 3.*—Stems about 7^{dm} high, slender, villous with long white hairs: radical leaves spatulate-oblanceolate; cauline linear, villous; the lower ones glabrate: head solitary, 1.5^{cm} in diameter:

involucral bracts linear-attenuate, densely clothed with purple woolly hairs, 5^{mm} long, very narrow: rays purple, filiform, about 50, 4^{mm} long; disk corollas tubular, with 5 purple teeth at summit: pappus barbellate, white: akenes hispid with spreading hairs.

Type range: "in Alpibus Lapponiae, Helvetiae."

164. PETASITES FRIGIDA Fries. Syll. 20. 1854–55. *Tussilago frigida* L. Sp. Pl. 865. 1753.—Leaves deltoid-ovate, deeply cordate at base, irregularly and deeply sinuate-dentate or lobed, the teeth callous-tipped; upper surface almost glabrous, lower white tomentose; petioles equaling or longer than the leaves, together 8^{cm} long: bracts of the flowering stem sheathing, scarious, sometimes foliaceous at apex: female plants with heads in corymbs; bracts of the involucre 1^{cm} long, subulate, a few linear calyculate bractlets at base: akenes linear, glabrous, obtusely ribbed, with loose outer coat: pappus 1.5^{cm} long.

Type range: "in Alpium Lapponiae, Helvetiae, Sibiriae, convallibus."

165. SAUSSUREA ALPINA DC. Prodr. 6:535. *Serratula alpina* L. Sp. Pl. 816. 1753.—Stems simple, 5^{cm} to 1.5^{dm} high, ribbed, loosely arachnoid-tomentose: leaves lanceolate, narrowed at base, strongly 1-nerved, loosely tomentose, with margins entire or revolute: heads 1–5; involucral bracts in 4 series, ovate, the outer successively shorter, purple, glandular-hairy; involucre 15^{mm} high: rays none: akenes black, glabrous, with plumose pappus: receptacle with slender chaffy scales among the flowers: corolla with linear divisions to the border, almost equaling the tube, rose-color.

Type range: "In Alpibus Lapponiae, Austriae, Helvetiae, Arvoniae, Sibiriae."

166. SENECIO FRIGIDUS Less. Linnaea 6:239. *Cineraria frigida* Richards (1823). Hook. Fl. Bor.-Am. 1:334. *pl. 112.* 1840.—Stems simple, 2-flowered, $12–15^{cm}$ high, glabrous below, clothed with brown floccose wool above: radical leaves oblong, dentate, on petioles nearly twice as long as the blade; lower stem leaves with broadly dilated clasping petioles; upper stem leaves sessile

by a clasping base, sparingly floccose-tomentose, few and diminishing upwards: heads large, terminal, solitary, almost 3^{cm} in diameter; involucral bracts densely clothed with brown wool, linear-oblong, acute, 6^{mm} long: rays about 14, oblong, 3-toothed; disk corollas with campanulate limb, the slender tube longer than the pappus: akenes striate, glabrous.

This may be another species, as it differs in the shape of the disk corollas. The limb in this is more abruptly contracted at base to a more slender and longer tube. In all other respects the two seem identical.

167. SENECIO LUGENS Hook., var. **Blaisdellii**, n. var.—Stems simple, $1.5–2^{dm}$ high, tomentose: radical leaves lanceolate-oblong, narrowed to a sessile base, denticulate, about 7^{cm} long, 1^{cm} wide (the earliest ones spatulate, much shorter and broader); cauline mostly near the base, narrowly acuminate, dentate below the middle; upper part of stem generally leafless to the inflorescence which is subtended by 1 or 2 leaves: head cymose, 3–5-flowered; pedicels more or less tomentose, the middle one generally half as long as the others; bracts of the inflorescence narrowly linear, black-tipped; involucre campanulate, with a few calyculate bractlets at base; scales oblong, acute, ribbed, tipped with dark purple, 5^{mm} long: rays linear-oblong, 6^{mm} long, 3–4-veined, obtuse or denticulate at apex: style tips truncate, tufted: akenes glabrous, striate.

This is much smaller in all its parts than the typical form as figured by Hooker, and has fewer heads.

168. SENECIO RESEDIFOLIUS Less. Linnaea **6**: 243. 1831.—Stems 1–2 from the base, $6–10^{cm}$ high: lowest leaves orbicular, crenate-dentate to lyrate-pinnatifid, on broad petioles dilated at base, glabrous or slightly tomentose: upper leaves smaller, sessile, narrowed to a slender acumination: heads solitary, terminating the stem: bracts of the involucre reddish-purple, narrowly linear, obtuse or pointed, 5^{mm} long: rays about 13, orange, 2–3-toothed or cleft, 12^{mm} long, 1.5^{mm} wide: akenes glabrous (very young), with barbellulate pappus: style branches tipped with a cusp surrounded by a tuft of hairs.

Type locality: "In sinu St. Laurentii."

169. SOLIDAGO MULTIRADIATA Ait. Hort. Kew. 3:218. 1789. —Stems erect, generally several from a woody rootstock, 2^{dm} high: radical and lowest stem leaves lanceolate-oblong, narrowed to margined petioles, equaling or much exceeding the blades in length, together $2–13^{cm}$ long, $5–10^{mm}$ wide, entire or serrate near the apex, veiny, white-woolly-ciliate especially on the petioles; stem leaves sessile: heads in a round or oblong glomerule, often with some looser and smaller clusters in the axils below: involucral bracts narrowly linear-acuminate, 4^{mm} long, ciliate: rays about 15, narrowly linear, $3–4^{mm}$ long: akenes pubescent.

Type locality: "Labrador."

170. TARAXACUM OFFICINALE LIVIDUM Koch, ex Gray Syn. Fl. 1:440.—Low, acaulescent, glabrous: leaves lyrate-pinnatifid, with petioles exceeding the blades, together $2–5^{cm}$ long: scape $5–7^{cm}$ long: involucral bracts turning black in drying; outer ones ovate, obtuse, slightly ciliate at the apex; inner longer, linear, with membranous margins: outer rays yellow, with black and white lines down the middle; inner ones clear yellow, ligulate, toothed at apex, almost 1^{cm} long: heads about 2^{cm} in diameter.

The following species, not included among Dr. Blaisdell's collection, were collected the previous year by Mr. George T. Ruddock at a place near Cape Nome known as Camp Teller: *Ranunculus Pallasii* Schlecht., *Lathyrus maritimus* Bigel., *Conioselinum Gmelini* C. &. R., *Androsace septentrionalis* L., *Castilleia pallida* Kunth, *Mertensia maritima* Don., *Artemisia borealis* Pall., and *Taraxacum Dens-leonis* L. var.

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BRIEFER ARTICLES.

HABERLANDT'S NEW ORGAN ON CONOCEPHALUS.[1]

PROFESSOR HABERLANDT'S contribution to the Schwendener *Festschrift* is an argument based upon previously published data,[2] in which he arrives at conclusions of such great importance, if well founded, that further discussion is certainly worth while. Let us begin with a statement of the facts in the case, in which literal quotations are made from the *Festschrift*.

The subject, *Conocephalus ovatus*, is a Javanese liane, with large, leathery leaves. On its upper surface are some hundred "Scharf differenzirte Epithem-Hydathoden mit Wasserspalten." "Bei keiner anderen Pflanze war die nächtliche Wasserausscheidung seitens der Hydathoden so constant und schön zu beobachten, wie bei der in Rede stehenden Liane." In a concrete case, a leaf ejected 26 per cent. of its own weight in water, in one night. When these hydathodes are poisoned, with 1 per cent. alcoholic corrosive sublimate, the excretion of water ceases. The next morning the leaf is dry outside, but there is "Eine oft sehr weitgehende Injection der Durchlüftungsräume mit Wasser." The water gradually disappeared, with active transpiration during the forenoon. This was repeated for three or four days; then there was a new response. "Auf den bepinselten Blatthälften entstanden nämlich zum Ersatze der vergifteten Hydathhoden ganz neue Wasserausscheidungsorgane von wesentlich anderem histologischen Bau und anderer entwicklunggeschichtlicher Herkunft, wie sie im normalen Entwicklungsgange der Pflanzen niemals auftreten." On subsequent mornings, drops were found on these structures, and the intercellular spaces were not injected. "Die neugebildeten Organe waren also vollkommen im Stande, die getödteten Epithem-Hydathoden in ihrer Funktion zu ersetzen."

[1] HABERLANDT, G., Ueber experimentelle Hervorrufung eines neuen Organes bei *Conocephalus ovatus* Tréc. Bot. Untersuchungen S. Schwendener dargebracht. Berlin, 1899.

[2] HABERLANDT, G., Ueber wassersecrnirende und-absorbirende Organe. Sitzber, Ak. Wiss. Wien. 1:55. 1895.

The substitute hydathodes are formed only where trichome clusters have given place to colleters, and the cuticle has been elevated and then split by mucilage. In their formation the tissue first concerned is the parenchyma of the bundle sheath, which enlarges greatly, breaks through the overlying tissues, and finally grows out into "Farblosen Haaren, die pinselförmig auseinander treten." The neighboring palisade parenchyma may share in this formation. The excretion of water is presumed to be, as in normal hydathodes, an active process. "Nachdem sie ungefähr eine Woche lang allnächtlich Wasser ausgeschieden haben, gehen sie allmählich zu Grunde." After their death, the leaf "Lässt auf seiner Unterseite durch Wucherungen der Epidermis und namentlich der darunter befindlichen Wassergewebsschicht zahlreiche ein-und mehrzellige Wasserblasen entstehen."

Haberlandt's argument from these data may be epitomized as follows. The substitute hydathodes are real *organs*, and not accidental structures, or purposeless results of injury to the plant, because they occur in particular places and are strikingly differentiated (the structural argument), and get rid of the plant's excess of water (the physiological argument). They are *new* organs because no similar structure is known on any part of Conocephalus or any related plant. Natural selection cannot have produced them because the occasion for them does not arise in nature; no known natural agent destroys the normal hydathodes, and they remove all the surplus water at the height of the rainy season. And natural selection would have made the substitute hydathodes reasonably permanent, instead of transitory. Summing up, so far, "Ein neues, zweckmässig gebautes und funktionirendes Organ ganz plötzlich, ohne früheres Vorbandensein einer rudimentären Anfangsbildung, ohne Vermittlung von sich allmählich vervollkommnenden Uebergangsstufen, und ohne die geringste Mitwirkung der Naturzüchtung entstehen kann. Bei der Erklärung des Zustandekommens der geschilderten Ersatz-Organe versagt die Selectionstheorie vollkommen ihren Dienst." The inadequacy of the theories of Nägeli and Weismann to explain completely the phenomenon is then shown; but a plausible solution based on them is reached. "Wenn nun auch ein besonderer Anlagenkomplex, eine eigene Determinante für diesen neuen Typus von Hydathoden im Idioplasma unmöglich vorhanden sein kann, so lässt sich doch wahrscheinlich machen, dass die einzelnen Elemente dieses Anlagenkomplexes im Idioplasma vertreten sind. Die Ersatz Hydathoden bestehen in ihren wesentlichsten Theilen aus

haarförmigen Schlauchzellen, denen die Fähigkeit einseitiger Wasserauspressung zukommt; sie verhalten sich also wie Wurzelhaare, die ja gleichfalls im dampfgesättigten Raume nicht selten die Fähigkeit besitzen, kleine Wassertröpfchen auszuscheiden. Nehmen wir nun an, dass in den Zellkernen der Leitparenchym, Palissaden-und Wassergewebszellen, die zu den Schlauchzellen der Ersatz-Hydathoden auswachsen, die idioplasmatische Anlage zur Haarbildung in Kombination mit der Anlage zu der eine einsitige Wasserauspressung ermöglichenden Struktur der Plasmahaut in Aktion tritt-Anlagen die im Idioplasma unserer Pflanze jedenfalls vertreten sind so erscheinen damit wenigstens die wichtigsten Voraussetzungen für die Entstehung der Ersatz-Hydathoden in der Struktur des Idioplasmas von vornherein gegeben."

If I have left any unclearness in Haberlandt's argument the fault is mine; it is not in the original. From the point where the new structure is recognized as a substitute hydathode, formed to relieve the plant of its surplus water, there is no escaping the conclusion that the theory of natural selection is inadequate and faulty. Nor is this all. Haberlandt concludes: "Ob man aber mit Rücksicht darauf, dass jene Entwicklungsvorgänge zur Entstehung eines *zweckmässig* gebauten und funktionirenden Organes führen, welches ganz ausserhalb des Bereiches der Naturzuchtung liegt, das Walten einer 'Entwicklungsintelligenz' annehmen soll, das zu entscheiden ist Sache des rein subjektiven Ermessens und Bedürfnisses jedes einzelnen. Die Naturforschung hat mit derlei metaphysischen Weiterungen nichts zu thun." But if we follow Haberlandt as far as he leads, we must balk sheer, or take the only remaining step of accepting the evidence of a design. And as surely as teleology is the natural enemy of modern science, it is a real concern of scientists whether or not they furnish material for its exponents. It seems to me that if Haberlandt's data admit of an interpretation freer from teleology, and otherwise more in harmony with the behavior of other plants, the more commonplace interpretation will commend itself.

Haberlandt's *dictum* that in judging the character of a new structure, "Nicht bloss die histologische und physiologische Beschaffenheit der sie aufbauenden Elemente, sondern ebenso sehr auch die jeweilige Kombination dieser Elemente in Betracht kommt," is a help to the clearest view of it only when the function does not follow directly from the structure, and when the units of structure are diverse in development. But when the performance of the function follows

obviously from the structure, and when all structural units are evidently formed in response to a common stimulus by a similar course of growth, then the introduction of the combination of elements as a feature distinct from the elements themselves is superfluous and cumbrous. In this case all the structural elements are similar hair-shaped cells, as stated in two quotations above ; that the stimulus to the formation of them all was the excess of water hardly admits of question. Formed from the original cells which do give rise to them, any essentially different arrangement or combination of these elements from that occurring is not conceivable. That is, the existing combination of the histological elements follows from their origin. The intimate connection of the histological and physiological features is constantly emphasized by Haberlandt ; his whole argument involves this, the "Zweckmässigkeit" of the structure. It is possible that the action of the substitute hydathode follows from its structure even more intimately than Haberlandt explains. There is nothing difficult to believe in his supposition that the excretion of water is active on the part of the cells.[3] Such one-sided activity may be manifested in the endodermis or other cells which force water into the xylem of all plants in which there is root pressure. And it would be only an assumption of a power of the epithem, analogous to many familiar correlations. But even this use of normally dormant determinants is not altogether necessary. Haberlandt says, "Auch eine passive Druckfiltration durch die lebenden Zellen der Ersatz-Hydathode ist nicht anzunehmen, da nicht einzusehen wäre, weshalb durch die turgeszirenden Hydathodenkörper das Wasser leichter durchgepresst werden sollte, als durch die lebenden Parenchymscheiden der Gefässbündel." Very thin walls and protoplasmic linings inside them would suggest easy filtration under pressure ; these are characters of the oedemata of tomato to be mentioned presently, and presumably of the structures in question on Conocephalus. More important than visible difference in the structure is difference in the turgor. As I have repeatedly shown,[4] the more rapidly cells grow, the less their turgor becomes. In the hypertrophied cells of the substitute hydathode there must be a very much lower osmotic pressure than in the cells from which they grew. The hydrostatic pressure in the tracheides at night exerts an equal force to

[3] Assuming, what is open to suspicion, that normal hydathodes act in this way.

[4] Ueber den Einfluss von Licht und Temperatur auf den Turgor. Halle a. S. 1896.

drive water through the bundle sheath into the intercellular spaces, and through the substitute hydathode into the free air; but the pressure thus exerted is much less in proportion to the osmotic pressure to which the protoplasm is accustomed in the bundle sheath. It might be anticipated then that through the substitute hydathode, where the excess pressure is relatively great, the water would escape.

After what has been said, I think it will be agreed that, given the structure of the substitute hydathodes as it is, there is nothing very surprising or remarkable in their behavior. It remains, then, to show that the structure is essentially similar to such as the same condition produces in many plants. The condition is excess of moisture. The chief characteristic of the structure is great hypertrophy of a group of cells.

Two years before Haberlandt first published his account, a paper appeared by Atkinson[5] on oedema of the tomato. When tomato beds in the forcing house were warmed so that root pressure furnished water faster than it transpired, or when water was forced into branches by connection with a faucet, these oedemata were developed. In my laboratory, Mr. T. C. Johnson caused their formation readily by forcing water into cut branches under a moderate head of mercury. The observations agreed entirely with Atkinson's, whom I therefore quote: "The epidermal cells were very much enlarged, while the chlorophyll bearing cells just beneath, as well as some of the more deeply seated cells, were greatly elongated in a radial direction, and strongly clavate at their outer extremity where this extended beyond the lateral pressure from adjacent tissue. In many cases the epidermal cells quickly separate and slough off. The cells of the affected areas possess exceedingly delicate walls, so that with little disturbance they would collapse. There was little protoplasm in proportion to the size of the cell and a corresponding amount of cell sap." "The increase in the number of cells in such cases," *i. e.*, when there is an increase, "occurs simply by the formation of transverse walls in the elongated cells." Later Atkinson speaks of "stretching of groups of cells to eight to ten times their normal size." The oedemata appear on the veins of the lower surface of the leaf blade (rarely on the upper surface), on the midrib, petiole, and stem. When water is forced into branches it emerges as drops along the edges of the leaves, or elsewhere, if any injury affords an

[5] ATKINSON, G. F., Oedema of the tomato. Rep. Agr. Exp. Stat., Ithaca, N. Y. 1893, pp. 101–128.

opportunity; to some extent the intercellular spaces become charged. In Atkinson's experiments the plants became wet; it probably did not occur to him to look for the extrusion of water from the sounder oedemata. In our experiments, instituted to see if this took place, the oedemata merely became wet when evaporation was prevented; drops of water were not excreted by them, however freely they might be forced out along the margin of the leaf. Evidently, though water can be forced through them, they are passive in the process, and the water escapes the easier way. But Atkinson says that water is set free by the collapse of hypertrophied cells: "The changes brought about by the escape of water from this and adjacent tissues during the warmer parts of the day may be so profound as to cause the leaf to wilt and die."

On the tomato then we have the same abnormal condition which caused the formation of the substitutes hydathodes of Conocephalus, producing structures which are like them in being formed on the veins, and in being formed from a group of cells of various tissues, which become tubular and segment below, and swell up at the free end; without doubt there are other details of resemblance—as in the thin walls and scanty protoplasm. Unquestionably, the two structures are homologous; but on the tomato the oedemata excrete little water, or the loss injures the plant. Their appearance is a pathological phenomenon, whose cause is clear; to seek to discover a purpose for them would be fatuous. Natural selection has provided the plant with responses to many frequently recurring pathological conditions. The ancestors of Conocephalus were always liable to mechanical injuries, and those whose wounds healed had in such cases an advantage; so the final cutting off of the substitute hydathodes by a callus may be ascribed to natural selection. But such exigencies as the loss of the hydathodes must have occurred to Conocephalus practically as rarely as corrosive sublimate entered them. Of course, natural selection is not responsible for the results. On grounds that we cannot yet elucidate well, even in theory, the hydathode responds to the corrosive sublimate by dying, and the leaf responds to the excess of water by the hypertrophy of groups of cells. The relation of cause and effect is equally clear, the details equally mysterious, in the two cases. We should see a purpose in both or neither. If the "Ersatz-Hydathode" admits of construction as evidence of the reign of an "Entwicklungs-intelligenz," the fatal action of corrosive sublimate must make us suspect the presence of a power of evil.

Science cannot make a discrimination between the structures on Conocephalus and tomato. Both must be regarded as oedemata, and it is merely incidental that those of Conocephalus temporarily furnish the easiest avenues for the escape of water under pressure. Haberlandt tells us truly that drops of water can be forced out through root hairs. That happens when the root is in the same condition as the Conocephalus leaves. It does not illustrate a "Zweckmässigkeit" on the part of the root hairs. It does not entitle them to be regarded as organs of excretion, emergency hydathodes. But there is only the same ground for calling the Conocephalus oedemata "organs," when they are of incidental temporary utility.

The position of the "substitute hydathodes," which Haberlandt regards as a striking feature, has not been discussd. They must be formed on the veins, because, as in the tomato, the water is most excessive there. And their appearance under old colleters is at the points of least resistance, where the cuticle is already ruptured and the walls have been partly softened. Atkinson says that oedemata on the tomato stem are formed in places where there are already large cells and "their walls are less resistant." If the oedema cells are even more slender in Conocephalus, as the figures would indicate, it is what should be anticipated from the firmer texture of the leaf.

The tomato has so far been used alone to furnish another instance parallel to that of Conocephalus, because it has been well worked out, and is an especially easy subject for such experiments. There are numerous other known illustrations. Haberlandt mentions the fact that Sorauer describes "Pathologische Veränderungen der Laublätter verschiedener Pflanzen, welche mit dem Bau der Ersatz-Hydathoden von Conocephalus eine gewisse Aehnlichkeit besitzen." After remarking the absence of proof that these structures are caused by excess of water (which proof has been given for the tomato), Haberlandt grants that they may be "Analoge Erscheinungen . . . . unvollkommene Ansätze zu einer Selbstregulation, die bei unserer Pflanze ganz unvermittelt in so vollkommener Weise sich einstellt."

Excessive moisture acts in the same way elsewhere than on leaves. Atkinson[6] describes an oedema on apple branches, resultant from excessive pruning and subsequent congestion with water. Their appearance on tomato stems has been mentioned. Ward (cited by

[6] ATKINSON, G. F., Oedema of apple trees. Rep. Agr. Exp. Stat., Ithaca, N. Y., 1893. pp. 305–307.

Atkinson) has reported them on potato stems. Devaux[7] describes oedemata on potato tubers kept saturated; they naturally appeared where the resistance to their growth was least—at the lenticels. Tubeuf[8] has reported what is doubtless the same result of excessive moisture on trees. They may also occur on roots in water.[9] Von Mohl[10] describes such structures formed under the influence of moisture from the lenticels and cortical parenchyma of *Salix viminalis* branches.

In plants whose normal habitat is wet, there has been an opportunity for natural selection to develop and utilize the excessive growth of the cells under the influence of water; and the utilization has been in several ways. The most common of these adaptations is aerenchyma.[11, 12] The oedemata of the lenticels of stems serve to connect perfectly the normal aerenchyma of water plants with the oedemata of leaves. It is a matter for individual judgment when it should be regarded as in the nature of a disease, and when as a normal structure. Even in water plants (Goebel *et al.*) its formation depends on the moisture and can be artificially regulated. It is not unusual for structures pathological in one plant to be normal in another. But no structure can be regarded as normal on a plant where it occurs too rarely for it to be subject to development by natural selection.

Goebel seems entirely justified in deriving the excessively light and porous tissue of Aeschynomene and other plants in water from aerenchyma. In these this tissue serves as a float. It is formed in the leaf of *Desmanthus* (*Neptunia*) *natans*, the petiole of the water hyacinth (Eichhornia), the stem of Nesaea,[13] and the root of Sesbania.[14] The

[7] DEVAUX, H., Hypertrophie des lenticelles chez la pomme de terre et quelques autres plantes. B. S. B. France. **38**: 48–50. 1891.

[8] TUBEUF, C. v., Ueber Lenticellen-Wucherungen (Aerenchym) an Holzgewächsen. Forst.-Naturw. Zeits. 405–414. 1898; Rev. in Bot. Centralb. **77**: 369.

[9] SCHRENK, H. v., Oedema in roots of *Salix nigra*. BOT. GAZ. **24**: 52. 1897.

[10] Verm. Schriften 259–332. Flora, 1832.

[11] SCHENK, H., Ueber das Aerenchyma, ein dem Kork homologes Gewebe bei Sumpfpflanzen. Jahrb. Wiss. Bot. **20**: 526–574. 1889.

[12] GOEBEL, K., Pflanzenbiologische Schilderungen II. 2. Die Wasserpflanzen. Marburg. 1893, p. 256 ff. *Fig. 69* is abnormal aerenchyma (oedema) in the lenticels, of *Populus nigra*.

[13] SCHRENK, J., On the floating tissue of *Nesaea verticillata*. Bull. Torr. Bot. Club. **16**: 315. 1889.

[14] SCOTT, D. H. and WAGER, H., On the floating roots of *Sesbania aculeata* Pers. Annals of Botany **1**: 307–314. 1888.

water acts on as various tissues to form these floats as are hypertrophied by it in oedemata.

I have not intended to cite any large part of the literature on this subject. For a fuller review of it Sorauer's *Pathology* and the work of Atkinson, Goebel, and Schenk referred to here should be consulted. The cases cited here are sufficient to show that excessive moisture produces on various parts of a great many plants structures essentially similar to those it causes on the leaf of Conocephalus.

A long list of cases similar to this is contained in a more recent paper by Sorauer,[15] in which he comes to the same conclusion with regard to Conocephalus that I have reached independently. Another very recent piece of work is by Miss Dale,[16] who finds that if other conditions are suitable moisture stimulates the formation of "hypertrophied outgrowths of epidermal cells, beginning at a stoma;" sometimes the underlying cells are also influenced. Her description and figure would fit almost perfectly for the raised stoma at the base of the hypocotol of Lupinus (BOT. GAZ. **31**: 413). From the fact that the same conditions of moisture which determine their development at the base of the hypocotyl (where the environment is normally very moist, or the seed would not germinate) do not give rise to them elsewhere on Lupinus, it seems likely that they are a product of natural selection and have a function — probably the increase in gas exchange with the air in or very near the ground. Miss Dale satisfies herself that the Hibiscus intumescences are pathological, but then looks for a function for them, suggesting that "they may be a sort of abnormal organ for the direct excretion of water." But they do not seem to have been observed to excrete it. From her results with Hibiscus and Ipomoea, she suggests that the "Wasserblasen" of Haberlandt's subject occurred on the nether surface of the leaf because the stomata are there.— EDWIN BINGHAM COPELAND, *Hull Botanical Laboratory, Chicago.*

[15] SORAUER, P., Ueber Intumescenzen. Ber. Deutsch. Bot. Gesell. **17**: 456–460. 1899.

[16] DALE, ELIZABETH, Investigations on the abnormal outgrowths or intumescences on *Hibiscus vitifolius* L. Phil. Trans. Roy. Soc. London. Bot. **194**: 163–182. 1901; also a note in Bot. Centralb. **85**: 372–375. 1901.

CURRENT LITERATURE.

BOOK REVIEWS.

Agricultural bacteriology.

WITHIN THE LAST DECADE great activity has been shown in bacteriological research along agricultural lines. The medical phase of the subject has controlled the major part of investigation so long that it has escaped the attention of many that in its other applications bacteriology is destined to exercise an important influence. Professor Conn[1] has certainly performed an important service by bringing together in popular form the results of these numerous investigations that bear on the different phases of agriculture. A perusal of these pages will indicate that the subject of agricultural bacteriology is indeed a broad one.

Part I includes a summary statement as to the nature of bacteria, and especially as to the principles of fermentation, that process which is of such far reaching importance in agriculture. Part II embraces a discussion of soil problems, as to the origin of soil and transformation which carbon and nitrogen undergo as a result of bacterial activity. The action of bacteria in dairy processes is considered in Part III, a phase of the subject which often receives special treatment under the head of dairy bacteriology. The various technical fermentations that occur in the formation of vinegar, tobacco curing, silage, and sugar industry comprise Part IV; while the principles involved in the various methods of preserving food products are discussed in Part V. The relation of disease bacteria as noted in maladies of farm animals is included in Part VI.

In a number of these processes, the previously accepted view that bacteria are the sole cause of the fermentative changes has been modified materially by the study of enzyme action that must be ascribed to other than bacterial sources. Professor Conn has included a discussion of these researches, even though their non-bacterial nature has been demonstrated. This broadens the scope of the book and at the same time greatly increases its value. The book is written in a pleasing, vigorous style that is designed primarily for the general reader. At the end of each part a brief bibliography is appended that will be helpful to students who wish fuller data as to the literature.— H. L. RUSSELL.

[1] CONN, H. W., Agricultural bacteriology. 8vo. pp. 412. Philadelphia: P. Blakiston's Son & Co. 1901.

Practical botany.

A FOURTH EDITION of Professor Strasburger's[2] well-known *Das kleine botanische Practicum* has just appeared and, like the previous editions, it is remarkable for the judicious manner in which the presentation of fundamental subject-matter is flavored with modern research. As before, there are thirty-two chapters, and the general method of presentation, which has proved successful, has been retained, so that a glance at the table of contents might lead one to imagine that little change has been made. An examination of the exercises, however, shows that the entire work has been carefully revised, that examples have been changed, and that every effort has been made to bring the book up to the present standpoint of botanical science. The number of forms studied has been somewhat reduced, on the ground that it is better to study a smaller number of forms thoroughly than a larger number superficially. A few of the improvements to which special attention might be called are as follows: a study of sensitive hairs and papillae, a study of double fertilization, a more extended study of protoplasmic connections with the latest methods of demonstrating them, and a particularly thorough revision of the chapters on bacteria and on cell and nuclear division. A large number of new figures has been added.

It may not be out of place in this connection to call attention to a book[3] which might be mistaken by the general student for an English translation of Professor Strasburger's work. In the first edition of the translation the translator added some notes of his own and also some additional illustrations, but all such matter was clearly indicated by brackets. In the second edition many of the brackets were eliminated, and in the last edition all brackets have been removed and the translator's notes incorporated into the text, so that it is difficult, and, for one who really needs a translation, impossible to distinguish what rests upon Strasburger's authority from that which has been inserted by the translator. Several figures have also been substituted. This is, to say the least, unfortunate, since in all of the German editions stress has been laid upon the fact that Professor Strasburger has drawn all the figures, and that all statements, even when they concern matters of common knowledge, rest upon his own investigations. Some of the statements, *e. g.*, referring to Cladophora as non-cellular, are directly contrary to Professor

[2] STRASBURGER, E., Das kleine botanische Practicum für Anfänger. Anleitung zum Selbststudium der mikroskopischen Botanik und Einführung in die mikroskopischen Technik. Vierte umgearbeitete Auflage. 8vo, viii+251, with 128 figures. Jena: Gustav Fischer. 1902. *M* 6.

[3] *Handbook of Practical Botany* for the laboratory and the private student, by Dr. E. Strasburger. Translated and edited from the German with many additional notes by W. Hillhouse. 5th ed., rewritten and enlarged. 8vo. xxxii+519. London: Swan Sonnenschein & Co. 1900.

Strasburger's published views. The addition of subject-matter more suited to a text-book is also to be criticised, since it makes the work too long for a manual, without being full enough for a text. These liberties seem hardly justified by the translator's remark in the preface that "the curious in such matters can doubtless disinter them (the translator's additions) by a comparison of the first English edition (in which all such additions were in square brackets), and of the German third edition, with the present issue."

While the fact that the translation has reached a fifth edition indicates that there is a demand for Professor Strasburger's *Practicum* in English, we believe it would have been better to have presented simply a translation, with an appendix indicating English and American types which could be substituted for the German forms when the latter are inaccessible.—CHARLES J. CHAMBERLAIN.

Engler and Drude's "Vegetation der Erde."

THREE MORE VOLUMES of this most important series have appeared lately, making five volumes already issued.[4] The recent treatises are on the Caucasus region by Radde, on the Illyrian countries by Beck, and on the North German heath by Graebner. Radde's work[5] alone will be considered here, but early attention to the others may be expected. In the historical account one is surprised to see the immense number of botanists who have worked in the Caucasian region of Europe and Asia; one of the first was Tournefort in 1717, another was the Russian botanist Güllenstädt in 1787. More recently Ledebour, C. A. Meyer, Ruprecht, Trautvetter, Albow, Krassnow, and a host of others have made this region well known botanically. Radde himself has written a large number of botanical papers relating to Caucasia, having worked there since 1854.

The first chapter deals with the steppes, which are found in their perfection north of the Caucasus mountains. As elsewhere, the steppes of Caucasia are of very recent geological origin; the famous "black earth" is the characteristic soil. A large portion of the steppe region has been artificially deforested. As in America, grassy steppes pass gradually into Artemisia half-deserts, or into thickets like our chaparral (Paliurus maqui). Along the streams poplars and willows occur as on our prairies. Sand dunes and halophytic areas are present in some places, the latter especially near the Caspian sea. Where artemisias now occur, halophytes were once present; before them was the sea, and still further back fresh water lakes. Thus the

[4] BOT. GAZ. 26:356. 1898.

[5] RADDE, DR. GUSTAV, Grundzüge der Pflanzenverbreitung in den Kaukasusländern von der unteren Wolga über den Manytsch-Scheider bis zur Scheitelfläche Hocharmeniens. 8vo, pp. xii + 500, with 13 text figures, 7 heliogravures, and 3 maps. Leipzig: W. Engelmann. 1899.

life history of the Caspian region closely resembles that of our salt lake districts. On the mountain slopes the steppes pass rather rapidly into forests. The steppes are best developed near the Black sea, while the halophytes and artemisias are more abundant toward the Caspian sea. Smaller and similar steppes are found south of the Caucasus, paths of migration occurring along the Caspian shore.

The second and third chapters have to do with the luxuriant forests of Colchis near the shore of the Black sea, south of the Caucasus, and the similar forests of Talysch near the Caspian. These forests enjoy a mild maritime climate and are largely of the Mediterranean evergreen type (Schimper's sclerophyll forests), in which the cypress, laurel, olive, arbutus, ilex, etc., are abundant, as well as a few deciduous trees; conifers are scarce. Some species now endemic in Colchis were widespread before the ice age, so that Wettstein believes that this region was a prominent place of refuge in the Pleistocene. Conditions are similar in Talysch, except that conifers are wholly absent. Other Caucasian forests are described in the fourth chapter. Western Caucasia has more forests than the eastern part of the district, a consequence of climatic differences. Ascending the mountains, one sees the Paliurus maqui pass into true forests of deciduous trees and conifers like those of Europe. Higher up are great Rhododendron thickets.

Xerophytic rock plants are treated in the fifth chapter. The characteristic forms are Persian, such as Astragalus and Acantholimon, and decrease northwestward as the climate becomes moister. Lists of calcicoles and silicicoles are given, but Radde tends to minify their importance. The next chapter is concerned with the mountain floras, which reach a high development in Caucasia. The snow and timber lines are much lower in the west Caucasus region than farther east because of the high precipitation, but there is no difference between the north and south slopes. The subalpine regions have a dense vegetation, in which Rhododendron takes an important place. In the alpine regions plants are scattered, and at least two species complete their life cycle a thousand feet above the snow line. Sphagnum bogs are confined to the alpine regions. The last two chapters contain phenological data and a floristic subdivision of the Caucasian region.— H. C. COWLES.

NOTES FOR STUDENTS.

K. SHIBATA has made an extended study of the course of growth and of the changes which occur in the reserve food during the development of the shoots of the bamboo.[6] These observations supply many details in the knowledge of the life history of *Phyllostachys mitis* and the other species used for comparative study.—C. R. B.

A VERY READABLE account of statistical methods as applied in biology is

[6] Jour. Coll. Sci. Imp. Univ. Tōkyō **13**: 427–502. *pls. 22–24.* 1900.

given by Whitney.[7] He describes especially the curves and charts of Karl Pearson based on the theory of probability. Very suggestive advances are being made in the manner in which masses of data may be handled and expressed in simple form.—B. M. DAVIS.

HABERLANDT reports[8] that he has confirmed the observations of Němc e[9] as to the existence of longitudinal fibrils in the protoplasm of plerome cells in Allium and Aspidium. He has identified these structures in living and in fixed tissues, but is not able to distinguish the sheath which Němec asserts to be present. He dissents, however, from the view that these are for the conduction of stimuli, and suggests that they serve rather for transport of plastic material.—C. R. B.

IN A THIRD PAPER on the proteolytic enzyme of Nepenthes,[10] Vines gives an abstract of the memoir of Clautriau[11] on digestion in the pitchers of these plants, and joins issue with him in various points. Vines holds "that the three enzymes, nepenthin, bromelin, and papain have essentially the same proteolytic action, which is tryptic," bromelin being most active, and nepenthin least. The latter also acts only in an acid medium; the others act best in a neutral one. Vines reiterates his former statement that all known proteolytic enzymes of plants are probably tryptic.—C. R. B.

THE ORIGIN of new species of plants has been recently treated from a botanical standpoint by von Wettstein.[12] He presents an extensive review of botanical literature bearing on Neo-Darwinian and Neo-Lamarckian theories, and concludes with a brief summary of his conclusions, the important points of which are as follows. High organization results from the fixing of adaptive characters by crossing and is largely modified by heterogeny; crossing and heterogeny play less important parts in the acquisition of adaptive characters; this stimulation comes through external factors, the plant having the ability to control its development by adaptation. It will be noted that this is a Neo-Lamarckian attitude.—B. M. DAVIS.

KUSANO[13] has recently made some extensive experiments on transpiration

[7] WHITNEY, Evolution and the theory of probability. Univ. Chron., Univ. of Cal. 3:402. 1900.

[8] HABERLANDT, G., Ueber fibrilläre Plasmastructuren. Ber. Deutsch. Bot. Gesells. 19: 569–578. 29 Ja 1902.

[9] Die Reizleitung und die reizleitenden Strukturen bei den Pflanzen. Jena. 1901.

[10] Annals of Botany 15:563–473. 1901.

[11] La digestion dans les urnes de Nepenthes. Mém. couronnés, Acad. Roy. Belg. 59:—. 1900.

[12] VON WETTSTEIN, Der gegenwärtige Stand unserer Kenntniss betreffend die Neubildung von Formen im Pflanzenreiche. Ber. Deutsch. Bot. Gesell. 18:184. 1900.

[13] KUSANO, Transpiration of evergreen trees in winter. Jour. Coll. Sci. Tōkyō 15:313–366. 1901.

of evergreen trees of Japan in winter. He found that the broad-leaved trees used in his experiments transpired per day 16.58$^{\text{gm}}$ per 100$^{\text{gm}}$ of fresh weight, and conifers 8.18$^{\text{gr}}$. The time of minimum transpiration agrees with that of minimum temperature, −5.9° C., and occurs at the end of January. These experiments, taken with those of Miyake,[14] who has shown that photosynthesis takes place without intermission in winter, seem to indicate that the abundance of evergreen trees in Japan is chiefly due to the favorable climate. The Puget sound region has a climate much like that of Japan, which may account for its great coniferous forests also.— H. N. WHITFORD.

STARCH FORMATION in Hydrodictyon is described by Timberlake.[15] There is no sharply differentiated chromatophore in this alga, the chlorophyll being distributed generally through the protoplasm between the plasma membrane and vacuolar membrane. The numerous pyrenoids are the centers of starch formation. Portions of the pyrenoids are cut off and changed directly into starch grains which lie in the surrounding protoplasm, arranged in such a manner as to show clearly their relation to the mother pyrenoid. The pyrenoid is then an active body contributing its substance to the starch grain. Kleb's distinction between pyrenoid and stroma starch in Hydrodictyon is not justified, for the latter are only older grains pushed away from the pyrenoids by the formation of younger starch. This study suggests interesting comparisons of other algal types with and without pyrenoids.— B. M. DAVIS.

AN ACCOUNT OF FERTILIZATION in another species of Pythium has appeared since the recent paper of Trow (Annals of Botany, Je 1901). Miyake[16] has investigated *Pythium Debaryanum*, and his results are essentially the same as those of Trow for *Pythium ultimum*. There is a mitosis in both oogonium and antheridium, the spindle being intranuclear as in Albugo. The contents of the oogonium becomes differentiated into ooplasm and periplasm, the nuclei taking position in the latter region. One nucleus enters the ooplasm from the periphery and becomes the functional female nucleus, those in the periplasm finally degenerating. There is no coenocentrum. A single male nucleus is discharged into the oogonium together with the greater part of the contents of the antheridium. Fusion of the sexual nuclei follows shortly. The investigation gives no data on the number of chromosomes in the various phases of the life-history.— B. M. DAVIS.

NOT LONG ago reference was made to the rather striking experiments of

[14] Bot. Centralb. **80**: 172.

[15] TIMBERLAKE, H. G., Starch formation in *Hydrodictyon utriculatum*. Annals of Botany **15**: 619–635. *pl. 34.* 1901.

[16] MIYAKE, K., The fertilization of *Pythium Debaryanum*. Annals of Botany **15**: 653–667. *pl. 36.* 1901.

Friedel,[17] who claimed that he had observed, apart from the living plant, the gas exchanges which are associated with photosynthesis. Macchiati[18] has discussed the significance of Friedel's results without adding many new facts of his own. Friedel[19] and Harroy[20] have repeated the earlier experiments of the former and obtained negative results. Friedel attributes this to the general weakening of synthetic processes in autumn, and promises to experiment on a large scale in the coming spring. He observed that young Pelargonium leaves show an activity in early summer that is twenty times that of similar young leaves in autumn, and that one scarcely ought to expect dead leaf material to exhibit gas exchanges at such an unfavorable period. Harroy, who repeated Friedel's experiments exactly and then improved upon the latter's experimental methods, concludes that Friedel's claim is premature, to say the least, though he admits its plausibility.—H. C. COWLES.

MITOSIS in the cells of Spirogyra presents difficulties that have led to a number of investigations with widely different results and much confusion. The last extensive paper on the subject is by Wisselingh.[21] The chief difficulties of the past have been the interpretation of nucleolus-like structures. Wisselingh finds generally one nucleolus for each nucleus, but sometimes two or more of varying sizes. Each has a membrane and contains a closely wound network, shown in certain stages of development to be made up of two long threads. The nucleolus of Spirogyra therefore shows many resemblances in structure to a nucleus. Outside of the nucleolus is a network filling the remainder of the nucleus.

There are two forms of mitosis, one with the formation of segments and one without. The segments are generally twelve in number, two coming from the nucleolus or two nucleoli, and the remainder from the nuclear network. These gather to form a nuclear plate at the metaphase of mitosis. Assuming that these segments are chromosomes, we then have in Spirogyra a form whose nucleoli are chromatic in character. However, the chemical nature of these bodies is not established, nor are all the stages of mitosis clearly explained.—B. M. DAVIS.

ITEMS OF TAXONOMIC INTEREST are as follows: R. CHODAT and E. WILCZEK (Bull. Herb. Boissier II. 2:281–296. 1902) have begun a critical enumeration of the plants of the Argentine Republic collected by Wilczek.—R. CHODAT (*idem* 297–312), in continuing his *Plantae Hasslerianae* from Paraguay, describes numerous new species of Compositae.—J. CARDOT and I. THERIOT (The Bryologist 5:13–16. 1902) have published some new and unrecorded mosses of North America.—E. L. GREENE (Ottawa Nat. 15:278–282.

[17] BOT. GAZ. 32:430. 1901.

[18] Bull. Soc. Bot. Ital. 1901: 323–335.

[19] Compt. Rend. 133:840–841. 1901.

[20] Compt. Rend. 133:890–891. 1901.

[21] WISSELINGH, Ueber Kerntheilung bei Spirogyra. II. Flora 87: 355. 1900.

1902) has described new species of Aster, Gnaphalium (2), and Arnica (4) from the northwest.—F. V. COVILLE (Proc. Biol. Soc. Washington **15**: 23–29. 1902) has discussed the confused synonymy of *Ribes aureum* and *R. lentum*.—C. L. POLLARD (Torreya **2**: 24–25. 1902) has described a new violet from New Jersey, and also (Proc. Biol. Soc. Washington **15**: 19–21. 1902) five new American species of Chamaecrista.—R. S. WILLIAMS (Bull. Torr. Bot. Club **29**: 66–68. *pls. 4–5.* 1902) has described new western species of Eurhynchium and Brachythecium.—CHARLES H. PECK (*idem* 69–74) has published thirteen new species of fungi.—ALICE EASTWOOD (*idem* 75–82. *pls. 6–7*) has described new Californian species of Fritillaria, Monotropa, Cycladenia, Potentilla, Orthocarpus, Spraguea, Sidalcea, Stachys, and Trifolium.—W. H. LONG, Jr. (*idem* 110–116) has described seven new Texan species of Puccinia, with illustrations.—F. GAGNEPAIN (Bull. Soc. Bot. France IV. **1**: session extraordinaire LXXIX. 1901) has published a new genus (*Aulotandra*) of Zingiberaceae.—J. M. C.

COWLES,[22] in a very comprehensive paper, gives the results of his observations on the influence of rocks on vegetation. The physical and chemical causes for different vegetation on different rocks is discussed. Attention is called to the facts that the resemblances, and not the differences, are the most striking, and that a number of factors have hitherto been neglected. Siliceous and calcareous rocks give rise to siliceous soils, so that there is more uniformity in the soils produced than in the rocks from which they were derived. The physiographic factor has also been neglected. No matter what the kind of rock, the ecological conditions will be much the same in the initial stages of erosion, and consequently the plants will be similar, while in the last stages of the life history the plants and conditions will be exactly the same. "The vegetation of all hills in a given region, of whatever chemical or physical nature, is tending toward an ultimate common destiny, which in most parts parts of the United States is the mesophytic forest. The succession of plant societies is sometimes slow and sometimes fast, and hence we have at any given period before the ultimate stage is reached a difference in soils. Were the stages equally rapid in all cases, there would be no such differences."

The author's researches comprise studies made on granites, gneisses, basalts, etc., in northern Michigan and in Connecticut, on quartzites in northern Michigan and in Montana, sandstones in northern Michigan, northern Illinois and in eastern Tennessee, shales in the Cumberland mountains of eastern Tennessee, and limestone and dolomites in Illinois, Wisconsin, Tennessee, and Montana.—H. N. WHITFORD.

[22] COWLES, H. C., Contributions from the Hull botanical laboratory. XXXIV. Bull. Am. Bureau Geog. **2**: 163–176, 376–388. 1901.

PROFESSOR HEGLER's work on the Cyanophyceae[23] has been expected ever since 1895, but poor health delayed the investigation. After the author's death, the manuscript, quite ready for the press, was published by Professor G. Karsten, who states that after the appearance of A. Fischer's work the author most carefully re-examined the disputed points, but without deeming it necessary to change his views. The photomicrographs with which the paper is illustrated do but scant justice to the beautiful preparations which the reviewer had the privilege of examining. About forty pages are devoted to a critical review of the literature of the subject. The rest of the paper, about eighty pages, contains an account of Hegler's prolonged investigations. The principal conclusions are as follows. There are no naked protoplasts in the Cyanophyceae, all cells being provided with cell membranes, which in the heterocysts consist of cellulose, and in the other cells consist principally of chitin. In the protoplast, or cell contents, may be distinguished an outer color-containing layer and an inner colorless portion. The coloring matter is in the form of extremely small granules so closely crowded as to give the impression of an homogeneous color. The chlorophyll and phycocyan are contained in the same granules and these granules are to be regarded as the chromatophores of the Cyanophyceae. Starch or starch-like material is not present, but glycogen can be identified and is the first recognizable product of assimilation. Albuminoid crystals and slime vacuoles are never found in the colorless, central portion of the cell. The albuminoid crystals are particularly abundant in the heterocysts and spores, but are often entirely lacking in rapidly-growing vegetative cells.

Whether a nucleus is present or not is the most important morphological question in connection with the Cyanophyceae and bacteria, since these are the only organisms in which a nucleus has not been positively identified. The bearing of this question upon present morphological theories of heredity is evident. Since previous methods have failed to solve the problem, the author devoted much attention to fixing and staining, and recommends the following: Saturated aqueous solution of SO^2, 7 parts; 94 per cent. alcohol, 93 parts; mix just before using and fix for 12–24 hours; wash with alcohol. Another fixing agent that gives good results is: 40 per cent. formalin, 5 parts; 94 per cent. alcohol, 95 parts; wash in 50 per cent. alcohol. The first-named fixing agent, however, allows a sharper staining of the nuclear figures. Fuchsin, safranin, and gentian-violet do not stain well; iodine-green and methyl-blue are better. The following method gave the best results: crystals of ammonia alum, 75 parts; water, 750 parts; dissolve the crystals in water, and add glycerin 125 parts, 94 per cent. alcohol 100 parts, and saturated alcoholic solution of haematoxylin 25 parts.

[23] HEGLER, ROBERT, Untersuchungen über die Organization der Phycochromaceenzelle. Jahrb. Wiss. Bot. **36**: 229–254. *pls. 5–6.* 1901.

The solution must stand for several weeks in a beaker, covered only by a piece of filter paper, before it is ready for use. Then stain for 24 hours in a mixture of 10 parts of the above solution in 100 parts of a 1 per cent. aqueous solution of formalin. Wash in running water at least one hour and then differentiate in saturated alcoholic solution of picric acid 1 part, water 1 part, and 94 per cent. alcohol 2 parts. The differentiation will generally require only a few seconds. Rinse in 75 per cent. alcohol and examine. If still too deeply stained transfer again to the differentiating solution and so continue until the stain is clear and sharp, then wash in running water for an hour, transfer to 50, 75, 94 per cent., and absolute alcohol, clear in toluol and mount in dammar.

From such preparations the following conclusions are drawn. The Centralkörper, or central body of the Cyanophyceae, is a nucleus. The most important reason for this conclusion is the behavior of the central body during cell division. In all cells of the Cyanophyceae, except the heterocysts, the nuclei of which degenerate very early, a single nucleus is present, its form depending largely upon the shape of the cell. The resting nucleus consists of a slightly staining ground mass in which are imbedded numerous, deeply staining granules. These granules from their behavior during division, their reaction to stains and digestive fluids, are to be identified with the chromatin granules of higher plants. They are not the "red granules" of Bütschli. The nucleus differs from that of higher plants in not possessing a nucleolus or nuclear membrane. During nuclear division the granules fuse into chromosomes which separate as division proceeds. Strands which represent spindle fibers may be seen between the separating groups. The wall first appears as a ring midway between the daughter nuclei and gradually grows toward the center until the partition is complete. The writer believes that he has shown positively that the Centralkörper is to be identified with the nucleus of higher plants.

It is interesting to note that Zacharias, in a lengthy and somewhat prejudiced review of Hegler's paper (Bot. Zeit. 59:322–327. 1901) disputes the accuracy of these conclusions and insists that there is no nucleus in the Cyanophyceae.—CHARLES J. CHAMBERLAIN.

NEWS.

Professor Volney M. Spalding, of the University of Michigan, is doing botanical work in Florida.—*Science.*

Geo. H. Shull, recently of the University of Chicago, has received an appointment as assistant in the U. S. National Herbarium.

Mrs. Mary L. Pulsifer Ames, the well-known Californian botanist, died March 20, at her home in San Jose, California, at the age of 57.

Mr. Elmer D. Merrill, assistant in agrostology in the U. S. Department of Agriculture, has accepted an appointment in the Philippines.

Frank Marion Andrews (University of Indiana) recently received his doctorate from the University of Leipzig, with the grade *summa cum laude.*

Professor Charles R. Barnes sailed for Europe March 22, to be absent nine months, during which time he will visit the principal botanical laboratories.

Dr. K. von Tubeuf, chief of the biological division, the German Department of Health, has been appointed professor of forestry in the University of Munich.—*Science.*

Dr. Max Koernicke, Privat Docent in botany, in the University of Bonn, has received an additional appointment as Privat Docent in the Landwirtschaftlichen Akademie of Bonn-Poppelsdorf.

Professor Bessey, of the University of Nebraska, is to give a course of twenty lectures on botany in the Colorado Springs Summer School, which is to be held in Colorado Springs, Colo., in July and Angust.—*Science.*

Professor W. H. Brewer, the well-known professor of Agriculture in the Sheffield Scientific School of Yale University, will retire from the active duties of his position at the end of the present academic year, after a service of thirty-seven years.

W. J. Spillman, agriculturist of the Washington Agricultural College and Experiment Station at Pullman, has succeeded F. Lamson-Scribner as agrostologist in the Department of Agriculture, Washington, D. C. Mr. Scribner sailed February 23 for Manila.

At the biological laboratory at Cold Spring Harbor the following courses in botany are offered for the summer of 1902: *Cryptogamic botany,* by Dr. D. S. Johnson, Johns Hopkins University; *Ecology,* by Samuel M. Coulter, Washington University; and *Bacteriology,* by Nelson F. Davis, Bucknell University.

THE FIFTY-FIRST MEETING of the *American Association for the Advancement of Science* will be held at Pittsburg, from June 28 to July 3. It is to be hoped that botanists will keep this meeting in mind, as it promises to be one of unusual interest in connection with the great meeting of scientific bodies to occur at Washington during the next Christmas holidays.

THE BRYOLOGIST has become a bi-monthly journal, and now includes not merely popular articles, but also technical papers. The features of the current year are a series of notes on nomenclature by Mrs. E. G. Britton; a continuation of the illustrated series on the lichens by Mrs. Harris; and of the liverworts by Mr. Barbour; and descriptions and illustrations of new and rare mosses. The editorial address is Mrs. Annie Morrill Smith, 78 Orange street, Brooklyn, N. Y.

THE BOTANICAL COURSES offered at Woods Hole during the summer of 1902 include cryptogamic botany, ecology, plant physiology, and plant cytology. The instructors are Drs. Davis, Moore, True, and Cowles, Professors C. H. Shaw and A. C. Moore, Mr. J. J. Wolfe, and Miss McRae. A more complete organization of the botanical supply department offers employment to a limited number of students who may thereby cover the tuition fees. Inquiries should be addressed to Dr. B. M. Davis, The University of Chicago.

IN *Science* for February 28[1] Dr. H. H. Field makes the welcome announcement that, in coöperation with the *Association Internationale des Botanistes*, the *Concilium Bibliographicum* will undertake the issue of a botanical bibliography on cards similar to those issued for several years in zoölogical lines. Two Zürich botanists, Dr. Stephen Bruneis and Mr. Emil Schoch-Etzensperger, have already been appointed to organize the work. Publication will begin in 1903. Botanists will await further announcements with interest. Every one is asked to add to his mailing list for separates the *Concilium Bibliographicum, Zürich-Neumünster, Switzerland.*

THE PART of the twenty-first annual report of the United States Geological Survey dealing with the Forest Reserves, to be published soon, will contain reports of the Lewis and Clarke forest reserves of Montana, the Mount Rainier and the Olympic forest reserves of Washington, the Cascade range forest reserve of Oregon, the Lake Tahoe and the Stanislaus reserves of California. The report also includes classification of timber lands in parts of California and Indian Territory, and a discussion of timber conditions in the pine region of Minnesota. The reports as a rule contain descriptions of the topography, the amount and distribution of timber, and the effect of fires and grazing on the forests.

[1] N. S. 15:357. 1902.

VOLUME XXXIII NUMBER 5

BOTANICAL GAZETTE

MAY, 1902

ON THE STARCH OF EVERGREEN LEAVES AND ITS RELATION TO PHOTOSYNTHESIS DURING THE WINTER.

KIICHI MIYAKÉ.

SACHS[1] suggested that in evergreen leaves the starch included in the chloroplasts might be stored there throughout the winter, but it seems that he did not make any observations of it. Mer,[2] by examining the contents of some evergreen leaves, found that the starch disappears at the end of October, to reappear again during the next March. Haberlandt[3] states that he found few starch granules in the palisade parenchyma of the leaves of *Taxus baccata* in winter.

Schulz[4] made a more extended study of the reserve materials of evergreen leaves in winter. He examined about a hundred species of plants, comprising both gymnosperms and angiosperms. All of the gymnosperms studied were found to be free from starch except *Gnetum Gnemon*, in which the green cells contained some starch-granules. Among the angiosperms all monocotyledons and some dicotyledons were free from starch, while the remaining dicotyledons contained more or less starch in the leaves. In many species, however, the starch was found only in

[1] SACHS, J., Microchemische Untersuchungen. Flora **20**: 289. 1862. (p. 300.)

[2] MER, E., De la constitution et des fonctions des feuilles hivernales. Bull. Soc. Bot. France **23**: 231. 1876.

[3] HABERLANDT, G., Vergleichende Anatomie des assimilatorischen Gewebesystems der Pflanzen. Jahrb. Wiss. Bot. **13**: 74. 1882.

[4] SCHULZ, E., Ueber Reservestoffe in immergrünen Blättern. Flora **71**: 223. 1888.

the fibrovascular bundles and the surrounding tissues. It was only in *Viscum album* and *Euonymus japonicus* that the green cells of the leaves contained some starch. More recently Lidforss[5] in examining the leaves of several winter-green plants, comprising herbs, shrubs, and trees, came to the conclusion that all green cells of plants are entirely free from starch during the winter months.

It seems, therefore, according to the observations of the above investigators, that almost all of the evergreen plants of northern and middle Europe lose the starch from the green cells of the leaves during winter. To know whether a similar state of things holds true in Japan, and to throw some light on the relation of leaf-starch to photosynthesis, I undertook the present investigation at the suggestion of Professor M. Miyoshi, to whom my sincere thanks are due for kind suggestions and helpful criticisms. The work was carried on in the Botanical Laboratory of Tokyo Imperial University, from August, 1898, until June of the following year.

There are various methods of testing for starch, all using iodine as the principal reagent. After some trials I determined to use Meyer's iodine-chloral method.[6] The leaves to be examined were directly observed, or kept in alcohol (70 per cent.) until examined. When fresh leaves were used, several thin sections were made from each of them, and placed in strong alcohol until the decoloration was complete. They were then placed on the slide, a few drops of chloral-iodine and potassium-iodide solution[7] being added, and examined under the microscope. When alcoholic material was used, the sections were immediately placed on the slide for examination.

Among the climatic factors the temperature plays an important part in the process of photosynthesis, and it would not be superfluous, before entering upon the account of my researches,

[5] LIDFORSS, B., Zur Physiologie und Biologie der Wintergrünen Flora. Bot. Centralb. 68: 33. 1896.

[6] MEYER, A., Das chlorophyllkorn. Leipzig, 1883.

[7] Prepared by mixing equal quantities of chloral-hydrate and water, to which a little iodine and potassium-iodide were added.

to make a short statement regarding the temperature of Tokyo and other parts of Japan during the winter.

Tokyo is situated in about the middle portion of the main island of Japan, 35°59′ N., 139° E. In January, the coldest month of the year, the temperature at night often falls several degrees below zero centigrade, but rises sometimes to 10° C. during the day. The mean average temperature of the three winter months in Tokyo, taken from the observations of the last twenty years in the Central Meteorological Observatory, is as follows: December, 5°.1;[8] January, 2°.7; February 3°.5. The winter of 1898–99 was a little milder than usual, the record being as follows: December, 6°.4; January, 3°.2; February, 4°.2.

The following table shows the mean temperature of several stations from which the alcoholic specimens of evergreen leaves were sent to me for examination:

Station	Location	Long. and Lat.	Dec.	Jan.	Feb.
Kumamoto ..	Kiushu island, southern Japan	32° 48′ N. 126° E.	6°.2	4°.4	5°.6
Kyoto[9]	Middle Japan	35° 1′ N. 136° E.	4°.2	2°.3	2°.7
Ishinomaki[10]	Northeastern Japan	39° 16′ N. 139° E.	2°.7	−0°.8	0°.2
Sapporo	Hokkaido island, northern Japan	43° 3′ N. 138° 5′ E.	−3°.1	−6°.3	−5°.0

For comparison I give the mean temperature for January in several localities of Europe and America:

Berlin, − 0°.8[11]	London, 3°.5	New York, − 1°.0
Munich, − 3°.0	Edinburgh, 3°.0	Washington, 0°.2
Hamburg, − 0°.4	Dublin, 4°.7	Boston, − 3°.4
Vienna, − 1°.7	Paris, 2°.0	Chicago, − 5°.0
Stockholm, − 3°.7	Marseilles, 6°.4	St. Louis, − 0°.5
Kopenhagen, − 0°.4	Rome, 6°.7	Montreal, −8°.4

[8] Throughout the paper temperature is expressed in centigrade.

[9] No meteorological station was found at Nara, where the material was collected, so I give the record of Kyoto, about twenty miles from Nara, and probably with nearly the same temperature.

[10] For the same reason as above I give the record of Ishinomaki, about twenty-five miles from Sendai, where my material was collected.

[11] These figures were taken from J. Hann, Handbuch der Klimatologie. 1883.

STARCH CONTENTS OF EVERGREEN LEAVES DURING THE WINTER AND AT OTHER TIMES.

I first examined a number of evergreen plants, including angiosperms, gymnosperms, and pteridophytes, for the starch contents of the leaves in August. The results generally correspond to the investigation of Meyer.[12] Thus, generally speaking, monocotyledons have little or no starch in the leaves, while dicotyledons, gymnosperms, and pteridophytes are found to be fairly rich in starch.

Then, during several months, from August to the following spring, I examined about eighty evergreen plants for their leaf-starch, the material being usually taken twice or three times a month. The leaves for examination were taken from various parts of the plants, the healthy and full-grown ones being selected. In many cases they were taken from several individuals of the same species. To determine the starch contents four to eight cross-sections were made from a single leaf, and for such sections five to ten leaves were used. Of eighty species examined the following seventeen were found to lose the starch from the mesophyll during the coldest part of the winter:

Ilex rotunda.
Ilex latifolia.
Magnolia compressa.
Magnolia grandiflora.
Ternstroemia japonica.
Daphne odora.
Andromeda japonica.
Aucuba japonica.
Geranium acutarium.*
Asarum Blumei.*
Ephedra vulgaris.
Picea hondoensis.
Podocarpus Nageia.
Aspidium falcatum.*
Polypodium ensatum.*
Polypodium lineare.*
Gymnogramme japonica.*

* Herbaceous plants.

As it takes too much space to describe the results with all the species above mentioned, I shall give only those with *Ilex rotunda*, as a representative.

[12] MEYER, ARTH., Ueber die Assimilationsproducte der Laubblätter angiospermer Pflanzen. Bot. Zeit. 43: 417. 1885.

ILEX ROTUNDA.

Date	Pal.[13]	Spon.	Stom.	M. t.[14]
1898, August 19	3–4[15]	3–4	II[16]	27.9
September 8	3–4	3–4	II	23.2
October 14	3–4	3	II	17.9
" 20	3–4	3	II	13.0
November 7	3–4	3	II	10.9
" 19	3	3	I	11.9
" 24	2	2	I	7.0
December 2	2	2	I	9.7
" 8	2	2	I	8.1
" 23	1	1	O–I	−0.9
1899, January 9	1	1	O–I	3.5
" 16	0–1	0–1	O–I	−1.2
" 31	0	0	?	3.0
February 8	0–1	0–1	O–I	4.5
" 27	2	2	I	8.5
March 6	3	3	I	8.9
" 29	4	4	I	12.7
April 25	5	5	I	13.9

The following twenty-seven species were found to contain very little starch in the mesophyll during the coldest time of the year:

Citrus Aurantium Bergamia.
Ilex crenata.
Thea japonica.
Thea sinensis.
Thea Sasangua.
Eurya ochnacea.
Nandia domestica.
Berberis napalensis.
Myrica rubra.
Photinia glabra.
Rhaphiolepis japonica.
Laurus nobilis.

[13] The following abbreviations are used in the tables: *pal.*, palisade parenchyma; *stom.*, stomatic guard-cells; *spon.*, spongy parenchyma; *m. t.*, mean temperature. It was found that in many leaves there is some difference in the starch contents between palisade and spongy parenchyma, and hence I have denoted the starch contents of the two regions separately.

[14] The temperatures in this and other tables are taken from the observations made at the Central Meteorological Observatory of Tokyo, which is about one and a half miles from the Botanical Garden, where most of my material was collected. I found that there is very little difference in temperature between the two localities.

[15] In designating the relative quantity of starch in the mesophyll, the following numerical signs are used: *0*, no starch; *1*, very little starch; *2*, little starch; *3*, moderately rich in starch; *4*, rich in starch; *5*, very rich in starch.

[16] The starch in the guard-cells of stomata was examined at the same time, and the amount is shown in the following way: *O*, no starch; *I*, little starch; *II*, rich in starch; *III*, very rich in starch.

Osmanthus fragrans.
Trachelospermum jasminoides.
Hedera Helix colchica.
Dendropanax japonicum.
Quercus Vibrayeana.
Euonymus japonicus.
Thymus serpyllum vulgaris.
Rhododendron Metternichii.
Eleagnus pungens.
Eleagnus macrophylla.
Torreya nucifera.
Taxus cuspidata.
Cunninghamia sinensis.
Sciadopitys verticillata.
Tsuga diversifolia.

In the following table the results with *Thea japonica* are given

THEA JAPONICA.

Date	Pal.	Spon.	Stom.	M. t.
1898, August 19..........	3	3	I	27.9
September 8........	3	3	I	23.2
" 21.......	4	4	I	20.5
October 13..........	3–4	4	I	15.3
" 21.......	2–3	3–4	I	17.3
November 7........	2–3	3–4	I	10.9
" 19.......	2	3	I	11.9
" 24.......	1–2	3	I	7.0
December 8.........	2	2	I	8.0
" 25.......	1	1	I	4.6
1899, January 9...........	1	1	?	3.5
" 31.........	1	1	?	3.0
February 8..........	1	1–2	0	4.5
" 27.........	2–3	3	0	8.5
March 13...........	2–3	4	?	4.1
" 23...........	2–3	4	?	10.4
April 11............	4–5	5	I	12.1
" 23....	4–5	5	I	15.3

The following twenty-one species were found to contain a little starch (2 in my scale) in the mesophyll during mid-winter:

Osmanthus aquifolium.
Actinodaphne lancifolium.
Gardenia florida.
Serissa foetida.
Rosa indica.
Pasania cuspidata.
Quercus glauca.
Illicium anisatum.
Fetsia japonica.
Skimmia japonica.
Ardisia japonica.
Pittosporum Tobira.
Ilex integra.
Saxifraga sarmentosa.*
Nasturtium officinale.*
Trachycarpus Fortunei.
Thuja occidentalis.
Chamaecyparis obtusa.
Abies firma.
Pinus densiflora.
Pinus Thunbergii.

* Herbaceous plants.

The results with *Osmanthus aquifolium* are as follows:

OSMANTHUS AQUIFOLIUM.

Date	Pal.	Spon.	Stom.	M. t.
1898, August 18	3	3–4	I	27.5
September 8	2-3	3–4	I	23.2
October 10	2	3	O–I	16.8
" 17	2	3	O–I	17.9
November 7	2	3–4	O–I	10.9
" 19	2	3–4	O–I	11.9
" 24	2	2–3	O	7.0
December 8	2	2–3	O	8.0
" 23	2	2–3	O	–0.9
1899, January 9	2	2	O	3.5
" 31	2	2	O	3.0
February 8	2	2	O	4.5
" 27	2	2–3	O	8.5
March 7	3	3–4	O	9.7
" 29	2–3	4	O	12.7
April 15	4	4–5	O	11.8

In the twenty following species, the mesophyll was found to be moderately rich in starch during the coldest period. They are the following:

Distylium racemosum.
Cinnamomum Camphora.
Viscum album.
Nerium odorum.
Daphniphyllum macropodum.
Eriobotrya japonica.
Juniperus chinensis procumbens.
Cryptomeria japonica.
Thuja orientalis.
Podocarpus macrophylla.
Cephalotaxus drupacea.
Thujopsis dolabrata.

The results with *Distylium racemosum* are as follows:

DISTYLIUM RACEMOSUM.

Date	Pal.	Spon.	Stom.	M. t.
1898, August 18	4	4	I	27.5
September 8	4	4	I	23.2
October 21	3–4	4	I	17.3
November 16	3	3	O–I	11.2
" 24	3	3	O–I	7.0
December 8	3	3	?	8.1
" 21	3	3	?	4.1
1899, January 9	3	2–3	?	3.5
" 31	3	2–3	?	3.0
February 8	3	2–3	?	4.5
" 27	3–4	2–3	?	8.5
March 7	4	3	O–I	9.7
" 29	4	4	I	12.7
April 23	5	5	I	15.3

The following table shows the starch contents of *Cinnamomum sericeum* and *Litsea japonica* in autumn, winter, and spring. It will be noticed how rich in starch these two plants are during the winter.

Name	Date	Pal.	Spon.
Cinnamomum sericeum	October 6	3–4	3–4
	January 31	4	4
	April 25	5	5
Litsea japonica	September 7	4–5	5
	January 18	5	5
	April 25	5	5

Thus among eighty species examined, the amount of starch in winter varies greatly in different species, the relation of the starch contents to the number of species being as follows:

Starch contents	0	1	2	3	4	5
Number of species	17	28	21	12	1	1

The majority of the evergreen plants were found to contain more or less starch in the mesophyll during the winter, though the amounts are generally much smaller than those at other times of the year. Only about one-fifth of the whole number of species examined became entirely free from starch, while some species were quite rich in starch during the coldest time of the year.

It can be seen, moreover, that the amount of starch during the winter does not depend much on the family to which the plant belongs. Taking members of Lauraceae, for example: *Laurus nobilis* has very little starch in the mesophyll during midwinter; *Actinodaphne lancifolia* has a little more, *Cinnamomum camphora* is moderately rich, *Cinnamomum sericeum* is richer, while *Litsea japonica* is very rich in starch. However, the mesophyll of all the ferns that I have examined[17] was entirely free from starch in midwinter, although the guard-cells always contain some starch.

Generally speaking, the amount of starch in the mesophyll begins to decrease in November and reaches its minimum during

[17] Besides the species of ferns already mentioned, I have examined *Aspidium varians*, *A. tripteron*, *A. lacerum*, *Pteris serrulata*, and *Lygodium japonicum*, in the coldest time of winter.

January and the beginning of February, increasing again from the end of February. As in the mesophyll, the amount of starch in the guard-cells becomes less or even entirely disappears in winter. Among the plants examined, less than half were found to have the stomata free from starch during midwinter. The increase or reappearance of stomatic starch was found to occur later than that in the mesophyll.

It should be noticed here that the starch contents of evergreen leaves are generally greater in April than in August or September. This fact was already noticed by Mer,[18] who remarked that some unknown internal causes may have an influence on the formation and accumulation of starch besides the known factors.

Lidforss (*l. c.*) noticed that the leaves are quite free from calcium oxalate crystals in winter, and he believes that this is favorable to the economy of plant life, since otherwise they would afford centers for ice-formation within the cells. Although not directly connected with my main object of study, I have examined carefully for the presence and amount of calcium oxalate crystals in the leaves of eighty evergreen plants at different times during the winter. I found the crystals in the majority of dicotyledonous leaves examined, and their amount did not decrease appreciably in winter.

Besides the plants already mentioned, I have examined some green herbaceous plants in the winter time. The results are as follows:

Name	Date	Pal.	Spon.	Stom.
Raphanus sativus	December 25	1	1	I
Raphanus sativus	January 18	1–2	1–2	I
Lamium album	February 12	0	0	I–II
Lamium amplexicaule	January 18	0	0	I
Senecio vulgaris	February 13	0	0	I
Campanula media	January 16	0	0	O
Stellaria media	January 18	1	1	?
Capsella Bursa-pastoris	January 18	2–3	2–3	I–II
Cynara Scolymus	January 18	0–1	0–1	I

[18] MER, E., Influence de quelques causes internes sur la présence de l'amidon dans les feuilles. Compt. Rend. 112:248. 1891.

As is shown in the above table, some herbaceous plants contain no starch in the mesophyll in winter, while others retain some. In many of the herbaceous leaves a little starch was found in the guard-cells of stomata.

Some monocotyledonous plants which contain very little or no starch in the mesophyll, but much in the guard-cells during milder temperature, were also examined in winter, and more or less starch was always found in the stomata, as is shown in the following table:

Name	Date	Pal.	Spon.	Stom.
Iris japonica................	December 5	0	0	II
Ophiopogon japonicus.......	January 7	0	0	I
Rhodea japonica............	January 7	0	0	III
Aspidistra lurida............	January 7	0–1	0–1	II–III

Thus we see that Lidforss's conclusion (*l. c.*) that the green cells of the plant, as well as the guard-cells, are entirely free from starch during winter months does not hold about Tokyo.

I have also examined many evergreen leaves collected in different parts of the country in winter and preserved in alcohol. The results are given below.

Evergreen leaves from Sapporo.

Through the kindness of Professor Miyabe of Sapporo Agricultural College, I have obtained alcoholic specimens of more than thirty species of evergreen leaves of that place, collected on January 22 and 25, and February 16. Among them the mesophyll of the following species was found to be free from starch:

Sciadopitys verticillata.
Pinus Thunbergii.
Pinus Strobus.
Pinus austriaca.
Pinus densiflora.
Picea excelsa.
Abies firma.
Abies sachalinensis.
Thuja orientalis.
Thujopsis dolabrata.
Podocarpus chinensis.
Taxus cuspidata.
Carex rhynchophylla.
Viscum album.
Ilex crenata.
Euonymus japonicus radicans.
Rhododendron brachycarpum.

The following contained little or very little starch in the mesophyll:

Cryptomeria japonica.
Pinus pentaphylla.
Pinus pumila.
Pinus ponderosa.
Picea ajanensis.
Juniperus chinensis.
Chamaecyparis obtusa.
Chamaecyparis obtusa breviramea.
Chamaecyparis obtusa pendula.
Chamaecyparis pisifera.
Chamaecyparis pisifera plumosa.
Ilex latifolia.

Hence we may say that in Sapporo the mesophyll of the majority of evergreen plants is almost free from starch during the coldest period of the winter. The guard-cells were also found to be almost without starch in the majority of the plants examined, about seven or eight species containing a little starch. Five species of dicotyledonous plants were found to contain the crystals of calcium oxalate in the leaves.

Evergreen leaves from Sendai.

The materials for study were sent to me through the kindness of Professor Yasuda of the Second Higher School of Sendai. They were collected on January 21 and February 13, 1899.

Of twenty-three species examined the following fourteen were found to contain no starch in the mesophyll:

Pinus densiflora.
Chamaecyparis pisifera filifera.
Sciadopitys verticillata.
Arundinaria Simoni.
Aucuba japonica.
Iris tectorum.
Rosa indica.
Nandia domestica.
Ilex crenata.
Andromeda japonica.
Euonymus japonicus.
Quercus glauca.
Photinia glabra.
Brassica campestris.

The following contained little or very little starch in the mesophyll:

Abies firma.
Cryptomeria japonica.
Thujopsis dolabrata.
Chamaecyparis obtusa.
Chamaecyparis obtusa breviramea.
Ilex latifolia.
Quercus Vibrayeana.
Thea japonica.
Thea Sasangua.

We may say that in Sendai also the mesophyll of the majority of evergreen plants is almost free from starch during midwinter. Guard-cells were free from starch in the majority of the examined plants, only five or six species containing a little starch. Calcium oxalate crystals were present, more or less, in almost all the dicotyledonous leaves examined.

Evergreen leaves from Nara.

The material was sent to me through the kindness of Mr. Aizama of the Nara High School, being collected in the cold days of January and February, 1899.

The results of the examination nearly correspond to those obtained from the plants of Tokyo. Among thirty-six species examined the following six contained no starch in the mesophyll:

Podocarpus chinensis.
Maesa Doraena.
Vicia Faba.
Eurya ochnacea.
Ternstroemia japonica.
Symplocos japonica.

Among the rest the following plants were found to contain little or very little starch in the mesophyll:

Podocarpus Nageia.
Pinus densiflora.
Pinus Thunbergii.
Nandia domestica.
Quercus glauca.
Citrus Aurantium Bergamia.
Rosa indica.
Photinia glabra.
Eriobotrya japonica.
Thea sinensis.
Thea Sasangua.
Thea japonica.
Eleagnus pungens.
Daphniphyllum macropodum.
Raphanus sativus.
Osmanthus aquifolium.
Ilex rotunda.
Ilex Oldhami.
Eurya japonica.
Illicium anisatum.
Ficus foveolata.
Raphanus sativus.
Osmanthus fragrans.

The following eight species were more or less rich in starch in the mesophyll:

Abies firma.
Cryptomeria japonica.
Nerium odorum.
Fetsia japonica.
Cinnamomum Loureirii.
Cinnamomum Camphora.
Cinnamomum pedunculatum.
Ardisia japonica.

About one-half of the plants contained some starch in the guard-cells, while calcium oxalate crystals were found in many leaves.

Evergreen leaves from Kumamoto.

The alcoholic specimens of evergreen leaves were sent to me through the kindness of Professor Aida, of the Fifth Higher School in Kumamoto. The leaves were collected at Kumamoto and its vicinity about February 20.

Of thirty-three species examined, starch was absent from the mesophyll of the following three:

Quercus glauca.
Quercus gilva.
Podocarpus macrophylla.

All the rest contained more or less starch in the mesophyll, and the following (more than one-third) were found to be rich or moderately rich in starch.

Citrus Aurantium Bergamia.
Cinnamomum Camphora.
Cinnamomum pedunculatum.
Daphniphyllum macropodum.
Gardenia florida.
Eriobotrya japonica.
Cryptomeria japonica.
Podocarpus chinensis.
Chamaecyparis obtusa.
Abies firma.
Pinus Thunbergii.

The remaining eighteen contained little or very little starch in the mesophyll, and are as follows:

Ilex latifolia.
Ilex integra.
Ilex crenata.
Ilex Oldhami.
Citrus Bigaradia.
Thea sinensis.
Thea japonica.
Euonymus japonicus.
Quercus sp.
Rosa indica.
Ligustrum japonicum.
Raphanus sativus.
Osmanthus fragrans.
Symplocos japonica.
Pasania cuspidata.
Thujopsis dolabrata.
Pinus parviflora.
Juniperus rigida.

Crystals of calcium oxalate were found in many leaves. It must be noticed that these results do not represent exactly that of the coldest time of the year in Kumamoto, as all the materials examined were collected in the latter part of February.

FORMATION AND TRANSLOCATION OF STARCH IN WINTER.

As stated before, many of the evergreen leaves in Tokyo contain more or less starch in winter. A series of experiments was performed to decide whether this starch is the product of photosynthesis going on in winter, or that which was formed earlier and kept there in the mesophyll without translocation. The experiments were mostly made with pot-plants, plants growing in the ground out of doors sometimes being used. The following plants were used in the experiments:

Thea japonica.
Fetsia japonica.
Rosa indica.
Andromeda japonica.
Cinnamomum Camphora.
Quercus Vibrayeana.
Eriobotrya japonica.
Hedera Helix colchica.
Ilex crenata.
Osmanthus fragrans.
Pinus densiflora.
Pinus Thunbergii.
Abies firma.
Podocarpus macrophylla.
Chamaecyparis obtusa breviramea.
Cryptomeria japonica.

The experiments were conducted between January 8 and the end of February. First of all, plants which contain more or less starch in the leaves were either put in the dark room [19] or covered with a black cylinder out of doors. After two or three weeks the leaves of most of the darkened plants were found entirely free from starch.[20] Then they were exposed to light. In most cases a small quantity of starch was formed after five to eight hours of exposure; in some cases it took ten to fifteen hours or more. The results of a few experiments are given below:

Thea japonica.

Two pot-plants were used, each about a meter high. On January 23, 1899, several leaves from each plant were examined for the starch contents and treated as below:

[19] During January and February, the temperature of the dark room was found to vary between 1°.0 and 7°.0 C.

[20] In some it took only ten days for the leaves to become free from starch, while in *Cryptomeria japonica* it took more than a month, probably due to the rich starch contents.

	Starch contents[21]			Treatment
A.	1-2	2-3	?	Put into the dark room.
B.	1-2	2-3	?	Remained out of doors as a check.[22]

At 9 A. M., February 10 (m. t. 3°.1, max. 8°.6, min. 2°.6) the leaves of both plants were examined, and it was found that the darkened plant had lost all of its starch in the leaves, while the starch of the check plant remained constant.

Then *A* was exposed to light out of doors. At 5 P. M. of the same day the leaves were again examined and the starch contents were found to be 1–2.

Fetsia japonica.

Two pot-plants, each about two-thirds of a meter high, were used. On January 23 the leaves of both were examined and treated as follows:

	Starch contents			Treatment
A.	3	3	I–II	Put into the dark room.
B.	3	3	I–II	Exposed to light out of doors as a check.

On February 17 the leaves of *A* were found to be free from starch, and the starch contents of *B* had remained constant. At 9 A. M. February 20 (m. t. 3°.4, max. 9°.7, min. −0°.8) the darkened plant was put into the light out of doors. At 5 P. M. of the same day the starch contents of *A* were 2, 2, I–II; and at 5 P. M. February 22 it became 3, 3, I–II.

Cinnamomum Camphora.

A small pot-plant about two-thirds of a meter high was examined for the leaf-starch at 2 P. M. February 9, and at once put into the dark room. The starch contents then were 2–3, 2–3. At 9 A. M. February 20, it was found that all the starch had disappeared from the mesophyll. The plant was exposed to light out of doors at noon of the same day, and at 5 P. M. of the same day the starch was found to be 1–2, 1–2, having been formed within five hours.

[21] The starch contents of palisade and spongy parenchyma, and of the guard-cells are denoted in three separate columns. It is moreover to be noticed that in *Thea japonica* the starch contents of small pot-plants are generally richer than those of the larger tree growing out of doors.

[22] In all experiments, the pots were buried in the ground to prevent the freezing of the earth.

Pinus Thunbergii.

Two pot-plants were used, each about half a meter high. On February 1 starch-contents of the leaves from both plants were examined and treated as below:

	Starch-content		Treatment
A.	3	?	Covered with a black cylinder.
B.	3	?	Check plant not covered.

The two put out of doors side by side.

On February 20 the starch had disappeared from *A*, and that of *B* had remained constant. At noon of the same day *A* was exposed to light, and at 5 P. M. the starch-contents were found to be 1–2, having been formed within five hours.

Abies firma.

Two pot-plants, each about a meter high, were examined for the leaf starch on January 23 and treated as follows:

	Starch-content			Treatment
A,	2–3	2–3	I	Put into the dark room.
B,	2–3	2–3	I	Remained out of doors as a check.

At 9 A. M., February 10, the mesophyll of *A* was found to be entirely free from starch. After exposure to the light out of doors, at 5 P. M. of the same day the starch was 1–2, 1–2, I; and at 5 P. M., February 11, the starch had increased to 3, 3, I.

In addition to these plants, several leaves of the following trees, which contain some starch in the mesophyll, were covered with tinfoil in the beginning of February: *Thea japonica*, *Quercus Vibrayeana*, *Sciadopitys verticillata*, *Osmanthus fragrans*, and *Ilex integra*. After two or three weeks the leaves were found to be entirely free from starch.

These experiments suffice to prove that many of the evergreen plants in Tokyo can form starch in the leaves by photosynthesis, and translocate it to other parts of the plant-body during the winter, though these processes may of course be much more feeble than at other times of the year. Hence the starch found in many evergreen leaves in winter may be considered as that which is formed during that season by photosynthesis.

BEHAVIOR OF STOMATA IN WINTER.

The continual exchange of gases between the intercellular spaces of the leaf and the surrounding atmosphere is necessary for photosynthesis, and this interchange is mainly through the stomata. Therefore, if the stomata be tightly closed, the photosynthetic process may practically be stopped in spite of favorable temperature and illumination.[23] Hence it would not be superfluous to note, the opening and closing of the stomata of evergreen leaves in winter, as observed in Tokyo.

Stahl[23] showed, in accordance with Schwendener[24] and Leitgeb,[25] that the stomata of evergreen leaves are closed during the winter, and also that the closed stomata of Taxus and Mahonia open after being kept for a week in a warm room, while those of Buxus and Hedera open after ten days. A similar fact was observed by Lidforss (*l. c.*) in the case of Saxifraga, Iris, and Lilium.

Darwin[26] verified the closure of the stomata of evergreen leaves in winter with his newly devised horn hygroscope. But he mentions some exceptional cases where they were found clearly open on January 20 (temperature 12°.5) in the warm winter of 1897–8, in *Prunus Laurocerasus*, *P. Lusitanica*, *Hedera Helix*, *Capsella Bursa-pastoris*, and *Cheiranthus Cheiri;* while *Buxus sempervirens* and *Ilex Aquifolium* had closed stomata.

For testing the opening of stomata I have adopted Stahl's cobalt test. The leaves, after removal, were brought immediately into the laboratory, the temperature of which varied from 15° to 17°, and covered with dried light-blue cobalt paper,[27] protected on both sides from the moisture of the air by two glass plates.

[23] STAHL, E., Einige Versuche ueber Transpiration und Assimilation. Bot. Zeit. 52:117. 1894.

[24] SCHWENDENER, S., Ueber Bau und Mechanik der Spaltöffnungen. Monatsb. Akad. Wiss. Berlin, 833. 1881.

[25] LEITGEB, H., Beiträge zur Physiologie der Spaltöffnungsapparate. Mittheil. Bot. Inst. Graz 1:1886.

[26] DARWIN, F., Observations on stomata. Phil. Trans. Roy. Soc. London Bot. 190:531. 1898.

[27] Prepared by soaking the filter paper in 2–4 per cent. cobalt chloride solution.

At 1 P. M., January 24, 1899 (half cloudy, temperature outside 7°), four plants were examined. The results are as follows:

Name	Observed facts	Stomata
Ternstroemia japonica.......	Reddening of cobalt paper took place within a few minutes on the under side of the leaf, while it remained blue on the upper for a long time.	Distinctly open.
Thea japonica.....	Very faint reddening seemed to occur after some time, but it is doubtful.	?
Fetsia japonica......	Same as preceding.	?
Sciadopitys verticillata.....	No reddening occurred on either side.	Closed.

At 2–2:30 P. M. January 31 (clear, temperature 6°), the following plants were examined:

Name	Observed facts	Stomata
Raphiolepis japonica.	Young leaf—cobalt paper quite red after two minutes.	Distinctly open.
	Old leaf—no reddening after thirty minutes.	Closed.
Ternstroemia japonica	Quite red after three minutes.	Distinctly open.
Osmanthus fragrans..	Reddening clearly seen after six minutes.	Open.
Sciadopitys verticillata	No reddening for a long time.	Closed.
Pinus densiflora......	Reddening after four minutes.	Open.
Quercus glauca......	Reddening clearly seen after four minutes.	Open.
Quercus Vibrayeana..	Reddening clearly seen after five minutes.	Open.
Quercus phillyraeoides	Reddening after five minutes.	Open.
Pasania glabra.......	Reddening after five minutes.	Open.

At 2 P. M. February 1 (rather clear, temperature 7°.5), the above four species of Fagaceae were examined again, and it was found that all of them had the stomata open as before.

The next day at 3 P. M. (temperature 8°), the following observations were made:

Name	Observed facts	Stomata
Thea japonica, *a*	Faint reddening after some time, but rather doubtful.	?
Thea japonica, *b*	Same as above.	?
Thea japonica, *c*	Reddening clearly observed within ten minutes.	Open.
Juniperus chinensis procumbens	Reddening after a few minutes.	Open.

It is to be noticed that in *Thea japonica* the leaves from the first two plants showed no distinct opening of stomata, while those from the third plant had open stomata. It seems, therefore, that there are some variations in the behavior of stomata of the same species, probably due more or less to the location of the plants.

It is evident that many of the evergreen leaves examined have stomata more or less open in day time during the winter.

SUMMARY.

1. The starch contents of evergreen leaves differ much at a given time according to the different species. Monocotyledons generally contain less starch than dicotyledons, gymnosperms, and pteridophytes, or even none in some species.

2. The starch in evergreen leaves, generally speaking, begins to decrease in November, reaching its minimum during January and the beginning of February, and increases again from the end of February.

3. Many evergreen leaves in Tokyo and other parts of middle and southern Japan contain more or less starch in the mesophyll, while it is entirely absent in some species in the coldest time of winter.

4. The starch found in evergreen leaves in winter is generally very little compared with that observed at other times of the year, but in a few species the starch is quite abundant.

5. This starch is formed by photosynthesis in winter, though feebly, and its translocation occurs in the same season.

6. The starch in the guard-cells becomes less or even entirely disappears in many species, while a few species contain a moderate amount throughout the winter.

7. The majority of evergreen leaves in the northern part of Japan nearly lose the starch from the mesophyll and guard-cells in winter, while a little starch is still found in some species.

8. The starch content of evergreen leaves is generally more abundant in spring than in late summer or early autumn.

9. The opening of the stomata in winter was observed in some evergreen leaves in Tokyo.

10. The entire absence of calcium oxalate crystals from the leaves in winter, as stated by Lidforss, could not be verified in the present investigation.[28]

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[28] A preliminary note, bearing the same title as this paper, was published in Bot. Mag. Tokyo 14:44. 1900.

THE RHEOTROPISM OF ROOTS.

FREDERICK C. NEWCOMBE.

(WITH FIFTEEN FIGURES)

(*Concluded from p. 283.*)

VI. LOCATION OF THE SENSITIVE AREA.

SEVERAL experiments were made by Juel[11] to locate the sensitive area. His tests were of two kinds. He cut off the apical 1.5^{mm} of the root of *Vicia sativa*, exposed the seedlings thus prepared to the water current, and found that rheotropic curves followed somewhat more promptly and with greater angles than in uninjured roots. So many seedlings were employed, and the responses were so uniform, that we are probabably justified in accepting the results as demonstrating a rheotropic sensitiveness of the roots in the absence of the apex. Juel's other device consisted in covering the apical portion of roots with caps of collodion. These caps varied from 2 to 7 or 8^{mm} in length. Sufficient experiments were made with the shorter caps to show that the root was sensitive throughout its elongating zone. With the caps 7 to 8^{mm} long only six roots were tested, and of these only two gave reliable positive curves, two remaining straight, and two growing through the collodion and bending positively. Juel explains the curves with collodion caps as due either to the pressure of the water being felt through the collodion or to the penetration of the water stream through the collodion.

1. *Experiments with water-jets.*

My first series of experiments to determine the extent of the sensitive area was made by the employment of fine jets of water directed against various small areas of the root. Each seedling used was fixed by wet cotton in a perforation in a cork closing the lower end of a short glass cylinder 1.5 to 3^{cm} in height. The seedling thus projected both above and below the cork. Its upper part was packed in wet cotton, while 5 to 10^{mm} of its

[11] Untersuchungen über den Rheotropismus der Wurzeln. Jahrb. Wiss. Bot. 34:507.

root projected for the application of the water-jet. At frequent intervals water was put into the small cylinder, and this slowly percolated through the cotton and ran down over the root, thus insuring constant moisture. The water-jets were secured by bringing the water from an elevated reservoir through glass and rubber tubes to small glass nozzles passed through corks which were adjustable in height on small movable standards. The water-jets as they left the nozzles were from 0.2 to 0.5^{mm} in diameter. Each jet was adjustable by a screw-clamp applied to the conducting rubber tube.

This method would seem to offer a somewhat delicate means of locating the sensory area of the root. The majority of roots gave a positive response, but most of the roots did not grow very well. This behavior may be ascribed to various factors. In spite of the precautions taken, the exposed roots of the seedlings were not always everywhere kept covered with moisture; the nutations of the roots made it extremely difficult to keep the water-jet on a precise area, though the experiments were constantly watched and readjustments made; and it was practically impossible always to keep the water stream from circling around the root, thus greatly extending the root surface exposed to the water stream. Besides these objections, it may be well to note that a fine water-jet properly meeting the root affects only a very small surface, and it may be that a larger area must be stimulated to bring forth a ready response. The following table will present the main features of results obtained when the water-jets were applied to the apical millimeter of the root-tips.

TABLE VIII.

GIVING RESULTS OF WATER-JETS APPLIED TO THE APICAL MILLIMETER OF THE ROOT.

Species	Period	Number of roots	+ Curves	− Curves	Neutral
Helianthus annuus ...	7 hours	4	4	..	..
Brassica alba........	4 to 6 hrs	14	6	2	6
Totals............	....	18	10	2	6

That the relatively small number of positive responses in the foregoing tests with *Brassica alba* does not necessarily indicate a lack of sensitiveness in the root-tip is shown by results following the application of the water-jet to the elongating zone, this part having been proved sensitive by Juel's work as well as my own. In one experiment with the highly sensitive *Brassica alba*, the water-jet met the root 2 to 5^{mm} above the tip, yet after a period of twelve hours, of the six roots only two were positive, while one was negative and three were neutral. However, in a total of four experiments of this nature with *Brassica alba*, the seventeen roots showed twelve positive, two negative, and three neutral. This is certainly less equivocal than the results obtained from the same species when the water-jet was applied to the apex.

In conclusion it may be said that the experiments with the water-jets have indicated a rheotropic sensitiveness for the apical millimeter of the root.

2. *Experiments with cylinders of paper and of collodion.*

Another series of experiments to locate the sensitive area was tried with cylinders of paper and others of collodion, in which were cut apertures to admit the streaming water. *Fig. 14* shows the form of these devices. The paper cylinders were made of thin paper held in form by paraffin, and the bottom closed by a bead of paraffin. The collodion cylinders were cast over small rods of sugar, the sugar being subsequently dissolved out by immersion in water. To prepare these rods commercial cane sugar was dissolved by heat and rolled into small rods between the hands. These were then rolled to the desired diameter between plates of glass. Apertures were cut at any desired location in these cylinders, a vane was attached to the upper end to keep the cylinder in a constant position, and enough paraffin applied to make the whole slightly buoyant in water.

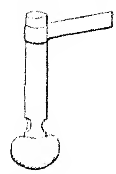

FIG. 14.—Illustrating the construction of collodion and paper cylinders used in locating the sensitive area.

These cylinders or stockings were slipped over immersed roots as the seedlings were suspended over basins of water like those already described. When the basin was set in revolution, the stockings behaved well, but results were not forthcoming. The failure was probably due in part to the interference of the cylinders with the direction of the water stream, and in part to their mechanical interference with the curving of the roots.

3. *Experiments with glass tubes.*

The third and most satisfactory method for determining the extent of the sensitive area was the employment of glass tubes of several patterns, by means of which definite parts of the roots were exposed to the water streams in the revolving glass basins, and definite parts were shielded from the streams. The experiments are divided into two groups, those testing the sensitiveness of the apical millimeter or millimeter and a half, and those testing the rest of the root.

a. Testing the sensitiveness of the apex of roots.

To determine the sensitiveness of the apex of roots, straight glass tubes 3 to 4^{cm} in length and 3^{mm} internal diameter were used. Seedlings of suitable size, usually not more than a half centimeter longer than the tubes, were selected for experiment. The tubes were held in water and the seedlings passed in, after which a little wet cotton was pressed in around the seedling by the use of a needle whose point was broken off. The cotton was pressed in firmly enough to hold the seedling in position, yet not too firmly, to allow the seedling to be moved up or down the tube. Preparations thus made were fastened to bars of wood by means of strips of blotting paper and rubber bands, as shown in *fig. 15*. The bar of wood, with its load, was next suspended with the glass tubes dipping into water in a glass basin on a centrifuge, the seedlings were carefully adjusted so that their tips projected 0.5 to 1^{mm} from the glass tubes, and the revolving apparatus was set in motion. In recording the results given below, data as to temperature and velocity will be omitted.

Each could be given, but it will be sufficient to say that temperature was in each case from 21 to 26° in water, and the velocity of water current was from 150 to 500^{cm} per minute.

With *Zea mays* (popcorn) three experiments were made. In the first, eleven roots were used. The tips were never allowed to project from the glass tubes more than 2^{mm}. Every half hour, or oftener if necessary, the roots were pulled up a little to bring them back to 1^{mm} of exposure. After 4 hours, four roots had bent positively with angles ranging from 5 to 20°; the other seven roots were neutral. The second experiment was, in conditions, in every way like the first, except that the period of the test was 8 hours. Ten roots were used, and five of them curved positively with angles of 15 to 20°; the other five roots remained neutral. The five curved roots at the conclusion of the experiment had all bent over in contact with the edges of the glass tubes. The third experiment was quite like the others, except that the roots were not allowed to protrude more than 1.5^{mm} from the tubes, and the period was 7 hours. Ten roots were used, and at the end of the trial six had bent positively and the other four were neutral. One of the responding roots gave an angle of 5°, one of 15°, and four of 20°.

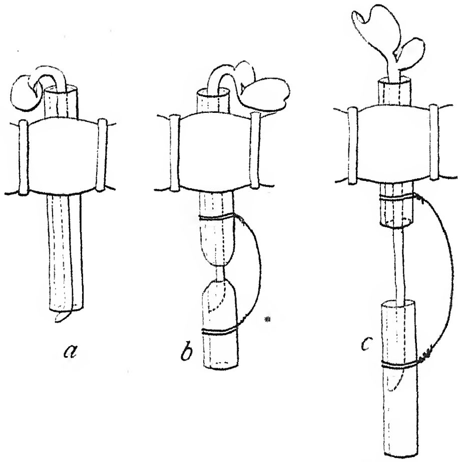

FIG. 15.—Illustrating the use of glass tubes in locating the sensitive area of *Raphanus sativus: a*, form of tube used in experimenting with the apex of the root; *b*, form used for exposing a narrow zone; *c*, form used in shielding a long apical section and exposing a long section back of the shielded portion.

With *Raphanus sativus* (Early Long Scarlet), results are still more decisive. In the first group thirteen seedlings were used. In 2¾ hours after the revolution began five roots were positive,

in 5 hours ten were positive, and in 6 hours all thirteen were positive. These roots had never more than 2^{mm} exposed. Another set of twenty seedlings with 1 to 1.5^{mm} of the apex exposed gave, after 8 hours, nineteen roots decidedly positive and one neutral. In a third experiment, the roots had a maximum of 1^{mm} exposed, each root being raised to 0.5^{mm} of exposed tip as soon as it approached the millimeter limit. Nine seedlings were used, and in 9 hours five roots had become positive, while the other four remained neutral. A final experiment, conducted exactly like the last, gave, after 9 hours, six roots positive with angles of 10 to 20°, while the other four roots remained neutral.

Unless serious objection can be brought against these experiments, they prove that the apex of the root is sensitive to the rheotropic stimulus. It may be objected by some that too much of the root was exposed, so that the elongating zone was affected by the current. This stricture can hardly hold when we consider that in one experiment with *Zea mays* not more than 1.5^{mm} was exposed, and in two experiments with *Raphanus sativus* not more than 1^{mm} was exposed. The root cap of this Raphanus has an axial depth of 0.3 to 0.4^{mm}, so that not more than 0.7^{mm} back of the cap was exposed, and this amount only for a small fraction of the period of the experiment. It may be thought that possibly there was a current in the tube itself at a greater or less distance above its lower end. This objection has been answered, to some degree at least, by two devices. In one experiment the lower ends of the tubes were contracted so that the root nearly filled the aperture; in the other experiment the space between root and tube was lightly filled with cotton. In both cases good curves were formed. In the first experiment, the bend in the roots took place above the constricted mouth of the tube, while the tip of the root extended obliquely through the narrowed opening. In the second experiment the bend took place in and below the cotton, the cotton not offering a very great resistance. Another answer to the foregoing objection lies in the fact that roots that were kept retracted within the tubes so that their tips were level with the lower end of the

tube never gave any curves. Contact with the side of the glass tube never effected any curvature. Scores of roots have been allowed to grow down through glass tubes, and many have by filling with cotton been pressed against the tubes as the roots grew out through the lower end, yet none have curved in quiet water. If we consider the proportion of the number curving to the total number of roots under experiment, we shall see that there is no ground here for objection to the assumption of the sensitiveness of the root-tip. In *Zea mays* almost half responded positively, and these were almost as many as have, in other experiments with the whole root uncovered, responded in the same time. In *Raphanus sativus* forty-three in fifty-two responded positively. That these curves were responses to the stream of water is readily believed when it is seen that there was not a single case of a negative curve. The curves were all relatively small, because the tubes stopped the progress of the curving; the curves were nevertheless decisive, being usually 15 to 20°, and to the author, who has during the past five years seen thousands of irritable curves in roots, there can be no doubt of the result.

From the foregoing experiments it may safely be concluded that the apex of the root is sensitive to a rheotropic stimulus.

b. Testing the sensitiveness of the root back of its apex.

In order to determine what part of the elongating zone of the root is sensitive, paired glass tubes constructed as shown in *fig. 15*, *b*, *c* were used. The tubes were 3^{mm} in internal diameter, were held together with fine annealed steel wire, and in each paired tube the ends that faced one another were narrowed. The tubes with their contained seedlings were held on supports as in the preceding group of experiments, and adjustments for the desired exposure of the root-surface were made as then, by moving the seedling up or down in the tube. It might be thought that the movement of seedlings up and down the tubes would interfere with results, either by injury to the roots or by bringing a different flank to meet the current. To overcome

this objection the seedlings were in several experiments fastened to the supporting bar by themselves and the encasing tubes were fastened to the same bar by a separate band just below the band holding the seedlings. Such a preparation enabled the glass tube to be moved up or down while the seedlings remained fixed. Results showed that there was no advantage in this more troublesome preparation, and it was discarded as unnecessary.

All of the following experiments were made with *Raphanus sativus* (Early Long Scarlet), the roots of this plant being insensitive to diffused light, and light being necessary at frequent periods of observation.

For the first series of experiments the apical 2^{mm} of the root were kept below the opening between the two parts of the paired tube, and not more than 2^{mm} of root were exposed to the water current. In one set of seven seedlings, at the end of 7 hours' revolution, five roots were positive 5 to 40°, while the other two roots were straight. In a second set of six roots, at the end of 4 hours 40 minutes, five were strongly positive, and the sixth root was straight.

These results show that the part of the root just above the apical 2^{mm} is sensitive.

In the next series of experiments ten seedlings were used whose apex was covered for a distance varying from 3 to 8^{mm}. Above the covered portion of the root, a portion 5 to 8^{mm} long was exposed. After 8 hours eight roots were positively bent and two roots were straight.

Five experiments, including forty-eight seedlings, were made, in which 10^{mm} of the apex of the roots were covered, and the root left exposed for 5 to 8^{mm} above the covered part. The duration of the experiments varied from 10 to 11 hours. At the end, thirty-four roots were positive, three were negative, and eleven were neutral.

Two experiments, including a total of twenty-three seedlings, were made in which 15^{mm} of the apex were covered, and 5 to 8^{mm} above the covered part were exposed. The duration of the experiments was in one case 10 hours, in the other 12¾

hours. Of the twenty-three roots, ten became positive, two negative, and eleven remained neutral.

Two experiments, including nineteen seedlings, were made, in which 20^{mm} of the apex of the roots were covered, and the roots left exposed for 5 to 8^{mm} above this portion. One experiment ran for 9 hours, the other for 11 hours. Of the nineteen roots, seven became slightly positive, four slightly negative, and eight remained straight.

The results here recorded are most interesting. They teach that the root is sensitive to the rheotropic stimulus at a considerable distance back of the elongating zone. The elongating zone in this variety of *Raphanus sativus* extends but 5^{mm} back of the tip. This fact I determined by marking ten roots with India ink, and observing them with a horizontal microscope at intervals during 24 hours. The roots were kept immersed in water. Growth was observed to take place in some roots in the first 4^{mm} only, and in the others in the first 5^{mm}. No root showed any elongation of the sixth millimeter. All conditions for growth were favorable, and good growth took place in each root.

Objectionable conditions were in these experiments removed as far as possible. The experiments were all performed within a period of five weeks, the temperature was held within a variation of one degree, the revolution of the basins was the same speed for all, giving in each experiment a range of velocities from 150 to 500^{cm} per minute, and the duration of the last three series, which are the only ones whose results might *a priori* be called in question, was nearly alike. To lessen the chances, if there were any, of a feeble stream being set up within the tubes themselves, the lower end of the lower tube was in some cases closed with a plug of cotton, in other cases closed by fusing. In still other experiments not only was the lower end of the lower tube closed, but cotton was packed around the root at its entrance into the lower tube. Thus it would seem that all possibility of a current within the tubes was excluded. The closing of the ends of the tubes is, however, not advisable; for

it tends to produce distortion in the roots after 12 to 15 hours of 23° or over. This may come from the lack of oxygen or the accumulation of the excreta of the root. The experiments recorded above, therefore, were performed with open tubes, except for the narrowing at the inner ends, as shown in *fig.* 15. The tips of the roots in all the experiments were kept from 5 to 15^{mm} removed from the lower open ends of the tubes. In several tests where the whole root was enclosed in a tube, the tip coming even with the lower open end, there was no curvature. The possibility, therefore, of curvature being caused by streams within the tubes may be dismissed.

The experiments show a decreasing sensitiveness in the roots from the region of the elongating zone back to a position at least 15^{mm} from the apex. When 20^{mm} of the apex of the root were covered there seemed to be some disturbance of the root but no pronounced directive influence. There were in this case proportionately more than twice as many negative curves as in any other set, while the number of positive curves was much less than in other experiments.

It is worth noting that the percentages of positive curvature in the four different sets show a constant decrease, being 80 per cent. in roots with 3 to 8^{mm} covered, 71 per cent. in roots with 10^{mm} covered, 44 per cent. in roots with 15^{mm} covered, and 32 per cent. in roots with 20^{mm} covered. The angles attained in these curvatures were often as great as the tubes would allow, and averaged 17° in the first series, 19° in the second, 18° in the third, and 11° in the fourth. Thus it is shown that when 20^{mm} of the root were covered the positive responses were relatively so few and gave such small angles that one may well suppose that the limit of sensitiveness has been approximated. Not so, however, with the portion of the radish root 15^{mm} from the tip; of the twenty-three seedlings used, nearly half gave good positive curves, and there were only two negative curves. The small number of negative curves is excellent evidence for the reliability of the result; for the absence of negative curves shows that the positive curves cannot be charged to pathological distortion.

If this evidence is reliable, it shows that the rheotropic stimulus is received and transmitted by a part of the root 10^{mm} removed from the limit of the elongating zone, and 12^{mm} from the part which first curves. Remarkable as this result may seem, I believe it will stand the test of time. One must master a certain amount of technique to obtain success; but the technique once learned, the preparation is easy and the results sure.

C. RESULTS WITH OLDER PLANTS.

I. WITH SECONDARY ROOTS.

It cannot be inferred *a priori* that the secondary roots of non-sensitive primary ones would be found non-sensitive, nor can it be inferred that the secondary roots of sensitive primary ones would be found sensitive. It seems to be true, however, that secondary roots are sensitive or insensitive according to the sensitiveness or insensitiveness of the primary root. Berg[12] found both primary and secondary roots positively rheotropic in *Zea mays*, *Fagopyrum tataricum*, *Tropaeolum majus*, *Lupinus albus*, *L. luteus*, *Vicia faba*, *V. sativa*, and *Helianthus annuus*, while neither order of roots in *Soja hispida* was sensitive. My own results are as follows:

Seven seedlings of *Cucurbita pepo* with short lateral roots protruding were suspended with roots immersed in a basin of water for two days. During this time, the basin was revolved for two periods, once for 24 hours and once for 16 hours. The lateral roots that could be counted as long enough for experiment numbered from thirty-five to forty, the shortest being 1^{cm} and the longest 5^{cm}. The temperature was 24 to 26°, and the velocity of current ranged from 300^{cm} for the slowest to 1200^{cm} per minute for the most rapid flow. All roots, both primary and secondary, grew well and grew straight.

Tropaeolum majus was tested in the same way, but in velocities ranging from 150 to 600^{cm} per minute. Only ten secondary roots were present, and unfortunately the test lasted only 12 hours. All roots grew straight.

[12] Studien über Rheotropismus. Lunds Universitets Årsskrift. 35^2: no. 6.

Zea mays (a yellow dent variety) was abundantly employed in several experiments. The seedlings with primary and secondary roots present were suspended in the usual way along the diameter of several glass basins. The temperature varied from 21 to 24° in air, and the velocity ranged from 150 to 600^{cm} per minute. The duration of each test was one week. Some hundreds of secondary and many tertiary roots were present in the latter half of the week. The primary roots, as usual in this species and variety, contorted very badly; the secondary and tertiary roots grew without contortion, and nearly all became strongly positively curved. Only two or three took a negative course, and not more than seven remained neutral.

The secondary roots of *Fagopyrum esculentum* were tested on ten seedlings which had their roots immersed in the water of a revolving basin for 41½ hours. The temperature varied from 23 to 28°, and the rate of flow ranged from 125 to 600^{cm} per minute. There were fifty secondary roots 1^{cm} long or over. Of the secondary roots, fifteen became positive, four negative, and thirty-one did not curve. Of the main roots, seven became positive, one became contorted, and two remained straight.

From the foregoing results one can hardly generalize, because the experiments are too few. Yet it is evident that in the two plants, *Cucurbita pepo* and *Tropaeolum majus*, whose main roots had been found insensitive, or but weakly responsive, to a rheotropic stimulus, the secondary roots are insensitive also; and that in the *Fagopyrum esculentum*, the secondary as well as the primary roots are sensitive, but the former much less sensitive than the latter. For the variety of *Zea mays* used, it may be said that the main roots always contort so badly in water that their relations in rheotropism cannot be determined. Other varieties of *Zea mays* (popcorn and those employed by Jönssen, Berg, and Juel) we know to be positively rheotropic in the main root. The experiments here recorded show the secondary and tertiary roots to be rheotropic also.

II. WITH ROOTS OF MATURING PLANTS.

To obtain the roots of older plants for experiment, special preparation was necessary. Flower pots were chosen of medium size, the bottom broken out and wire netting placed for a bottom. The netting had meshes a little over 2^{mm} in diameter. In these crocks seeds were planted, and the crocks set on a stone slab outdoors, the season being summer. This treatment prevented any great growth of roots through the bottom of the crocks. When the plants had grown to suitable size, the crocks were set into battery jars, the crocks closing the opening of the jars and leaving a free space as a damp chamber below the crocks. The whole preparation was then sunken into the ground, and thus the light was excluded. Such preparations soon gave a good growth of roots down below the crocks. When the roots had attained suitable size, the crocks were lifted out of the jars and set over glass basins with the exposed roots immersed in water. By the revolution of the glass basins, a current of water was generated as in the preceding experiments. The roots that were used in the experiments were probably in no case primary. It is most probable that all primary roots had died at the tip in growing through the bottom of the crock while the crock was sitting on the stone slab.

Hordeum vulgare was used when the plants were 30 to 37^{cm} above ground and were flowering. Twenty-six good roots appeared. The first curves were noted in 20 hours after the revolution of the water basin began. The experiment continued for 50 hours, in air temperature of 24°, and velocities ranging from 100 to 400^{cm} per minute. Twenty-two roots bent positively with angles of 45 to 90°, and four roots remained neutral.

Cucurbita pepo, in the same conditions of temperature and current as Hordeum, was kept in the water stream for 84 hours. The plants were a month old and were in flower. Fifty roots were subjected to the current, but not one bent from a straight course.

Helianthus annuus, a month old, was tested in the same manner as the foregoing plants. There were thirty-two good

roots. Of these, twenty became positive, five negative, while seven did not curve.

Fagopyrum esculentum, the plants having nearly ripe fruit, and treated as the foregoing species, gave twenty-four roots for experiment. After 38 hours, fourteen roots were positive, four were negative, and six were contorted.

Raphanus sativus, a month old, furnished twenty-eight roots for experiment. No curves appeared for the first 20 hours. After 50 hours of revolution of the basins, twenty-one roots had positive curves of 45 to 90°, three were contorted, and four were straight.

Again it appears here that the sensitiveness of roots to a stream of water is neither lost nor gained in increasing age of the plant. In the preceding chapter it was indicated that the secondary roots are less sensitive than the primary. The same conclusion is much more strongly indicated by the experiments just narrated. Yet one may not argue too strongly from these last experiments. Plants growing in crocks are probably not very vigorous, and tests have shown over and over again that lack of vigor inhibits irritable responses. To cite a single case, I may say that a crock of plants of *Helianthus annuus*, not in a vigorous condition, was kept for 60 hours over revolving water with two dozen roots immersed, and no curvatures appeared.

D. NATURE OF THE RHEOTROPIC STIMULUS.

The nature of the rheotropic stimulus has not been determined. In the paper read before the American Association for the Advancement of Science[13] in 1896, I suggested that the rheotropic stimulus was pressure. Juel (*l. c.*) has renewed the suggestion, but no one has offered any direct evidence. The physiological importance of rheotropism is difficult to perceive, and hence one suspects here a case where the mechanism developed in response to some biologically important stimulus is set in motion by some other stimulus, as an electric current throws a muscle into contraction.

[13] BOT. GAZ. 22: 242. 1896.

If one considers the more common responses of roots, he will soon become convinced that rheotropism is none of these. Since the publication of Czapek's[14] hypothesis as to the means of the perception of the geotropic stimulus, one may even think of the possible connection of rheotropism with geotropism. If the direction of gravitation is perceived by the radial pressure of the layers of cells upon those more deeply lying, the pressure on one side of the root in flowing water would stimulate the gravitation pressure, and might call forth a pseudo-geotropic curve, the rheotropic curve. Since, however, it is almost certain that the gravitation stimulus is perceived by only the apical 1 to 2^{mm} of the root, and the rheotropic stimulus is perceived by 10 to 20^{mm} of the root, it is not probable that rheotropism is simulated geotropism.

Rheotropism is not necessarily connected with heliotropism; for several species, *e. g.*, *Raphanus sativus*, have been found rheotropic which are not heliotropic. Nor is rheotropism connected with hydrotropism; for, as demonstrated by Pfeffer,[15] in hydrotropism only the apical 1 to 2^{mm} of the root is sensitive. Rheotropism cannot be traumatropism; for in the former the response is the same when the stimulus is perceived by the tip of the root as by the part farther back. Aerotropism has been appealed to by many to account for various curvatures of roots in water. I have tested several species of plants with rheotropic roots for aerotropism, by bringing submerged chambers of air within a few millimeters of the side of root-tips which were several centimeters below the surface of water. The confined air was in most cases separated from the roots by parchment paper. In other cases there was no membrane intervening, the submerged chamber being tilted so as to hold the air, while the roots were brought within a few millimeters of the edge of the air-containing chamber. In none of these cases were the roots caused to deviate more than 5 to 10° from the vertical direction, and the

[14] Untersuchungen über Geotropismus. Jahrb. Wiss. Bot. **32**: 224.

[15] On this topic see Rothert, Flora **79**: 212. 1894; and Czapek, Jahrb. Wiss. Bot. **35**: 316.

majority of roots in any one preparation were unaffected. Rheotropism, therefore, is not aerotropism.

Lastly, we may ask what the probability is that rheotropism is response to pressure. On the one hand we know that the water current exerts one-sided pressure on the roots, and we are at a loss to perceive any other influence which the current may exert. On the other hand, a response of roots to pressure, either a positive or a negative response, has never been demonstrated. Sachs[16] thought he had found roots positively thigmotropic when stimulated on the elongating zone; but the curves produced were traumatic, as a forthcoming paper of mine will show. Darwin's[17] supposed negative thigmotropic curves of the root tip have been shown to be traumatropic by Wiesner[18] and Spalding.[19]

If the rheotropic curving is due to pressure, it might be thought that solid particles in the water stream might cause either an earlier or a greater response. Two experiments were tried with seedlings of *Helianthus annuus*, in one of which wheat flour was stirred into the water stream and in the other clay was used. In each case a control was set up with roots in water filtered through a Berkefeld filter. While the water was revolved the solid material was stirred up every half hour. In the first test the roots gave a readier response in the filtered water than in that containing the flour; in the second case, responses appeared at about the same time and the roots attained about the same angles in both basins.

There is no evidence to show that roots are sensitive to pressure, and until that is shown it is idle to speculate as to the relation of rheotropism and thigmotropism.

E. SUMMARY.

I. STATEMENT OF CHIEF RESULTS.

The foregoing pages narrate the results obtained in experiment with thirty-two species of plants. These thirty-two species

[16] Arbeit. aus. d. bot. Inst. Würz. 1: 437.

[17] Power of movement in plants, 1880, p. 129.

[18] Das Begwegungsvermögen der Pflanzen, 1881, p. 139.

[19] On the traumatropism of roots. Annals of Botany 8 : 423. 1894.

include all plants but two that have been tested by others for rheotropism, and twenty-one species that have never been experimented with before. In my own work and that of others, therefore, thirty-four species have been used. Of these, twenty have proved positively rheotropic, and fourteen have been found insensitive. *Rheotropism cannot therefore be said to be a general phenomenon.*

The foregoing experiments teach nothing more clearly than that sensitive species differ greatly in the degree of sensitiveness to a stimulating water current. As with almost any other irritable response, one may arrange species in a series according to their rheotropism. The twelve species of plants reported as rheotropic by Jönsson, Berg, and Juel should all be accounted as but feebly or moderately sensitive as compared with five *Cruciferae* and *Zea mays* (*everta* Sturt.) as reported in this paper.

The fourteen species found insensitive are distributed through nine families, and the twenty sensitive species through six families. Several species in a single family have been tested in the case of the *Gramineae* with five species in five genera, the *Leguminosae* with ten species in seven genera, the *Cruciferae* with six species in three genera, and the *Cucurbitaceae* with two species in two genera. All five species of the *Gramineae* are sensitive, five species of the *Leguminosae* are sensitive and five insensitive, five species of the *Cruciferae* are sensitive and one insensitive, and both species of the *Cucurbitaceae* are insensitive. Two or more species in each of five genera have been under experiment, and in each genus the species have been either all sensitive or all insensitive. *There is an indication therefore that the roots of genetically related plants behave alike toward a water current.*

On the other hand, of two varieties of *Lupinus albus* tested, one gave no response, while the other showed itself fairly responsive; and of the varieties of *Zea mays*, all the large fruited forms were but feebly affected, while the popcorn was very sensitive.

The four aquatic plants and the semi-aquatic *Nasturtium officinale* are none of them sensitive to the water stream. It is

hardly probable, therefore, that rheotropism stands in any biological relation to water plants.

Berg in his paper was unable to determine whether the velocity of water current had any effect on the response. Juel, working only with *Vicia sativa*, obtained only straight or negatively bent roots in velocities as high as 1800^{cm} per minute, while positive curves appeared in the majority of cases in velocities from 1.8 to 1800^{cm} per minute. The highest percentage and the strongest curves were found in velocities between the extremes named; the lower limiting velocity was not found. In my experiments data were obtained on the action of several species in varying velocities of water. *It has been shown that velocities above* 1000^{cm} *per minute give generally negative (mechanical) curves, that the optimum velocity lies between* 100^{cm} *and* 500^{cm} *per minute, and that velocities below* 50^{cm} *per minute bring fewer and slower responses with smaller angles.* The remarkable result was obtained of finding the main root of *Raphanus sativus* rheotropic in a velocity less than 1^{cm} per second, while the directive influence of a velocity of 2^{cm} per second was no longer obeyed by the main roots of *Brassica alba.* It should be remembered, however, that the character of the curve in these very weak currents differs greatly from that shown in optimum currents, the actual curves in the latter becoming mere positive inclinations in the former.

The latent period for rheotropism was stated by Berg to be for *Zea mays* one hour with the reading microscope; while that of *Vicia sativa* according to Juel is two hours. Table VII on p. 272 of this paper shows the shortest latent period obtained for eight species of plants. There it is seen that species differs greatly in time of response, though the latent period for all is relatively long compared with that for geotropism. Compared with the heliotropic response, the geotropic response of *Brassica alba* and *Helianthus annuus* is not much slower. The actual latent period for rheotropism has not, however, been determined by anybody for any plant. In the first place, the experiments have not been carried on in the optimum temperature for growth; and in the second place, all experiments, so far, have been inter-

fered with by geotropism. In my own study some experiments were made in which the effect of gravitation was sought to be eliminated by using the centrifuge revolving with vertical disk under water. The plan is wholly feasible, but in my work was not pursued far enough to give final results.

In the competition between geotropism and rheotropism, which comes into play from the method of experimentation, some roots attain only a small deviation from the vertical, some reach 45°, and some 90°, the last seeming to overcome their geotropism wholly. When the definitive angle is attained by a root, this angle is retained for an undetermined period. Only in the case of weak stimuli have roots been observed to lose their responsiveness to the water stream and to resume their vertical position while the water stream still continued.

The occurrence of the geotropic counter-curve is explained in assuming that the resultant position of equilibrium for roots in which geotropism and rheotropism are competing is different in the apical 2^{mm} from what it is in the part of the root farther back. This difference in position of equilibrium for the two parts of the root is due to the extent of both the sensitive and the motor zones. The first curve in ordinary geotropic bending being located, in roots of medium size, not more than 2^{mm} from the apex of the root, the apex bends down when rheotropism is carrying the root beyond the resultant position of equilibrium. The geotropic sensitiveness being confined to the apical 2^{mm}, the part farther back is, by the sinking of the sensory zone, released to some degree from its impulse to bend downward. As there is in the experiment a continuous rising of the part of the root posterior to the apical 2^{mm} as growth goes on, we must assume that the motor zones for geotropism and for rheotropism, in this kind of experiment, are in different parts of the root—the former being within 2^{mm} of the apex, and the latter three or more millimeters from the apex.

The present paper has given evidence for the rheotropic sensitiveness of at least 15^{mm} of the apex of the root. By means of fine jets of water directed against the apical millimeter of the

roots of *Helianthus annuus* and of *Brassica alba*, ten positive curves in a total of eighteen roots were obtained. The other eight roots all remained straight. The relatively small proportion of curves was doubtless due to the shortness of the period of the experiments and to the technical difficulties involved in the method. By shielding from the water stream by a glass tube the whole root of *Zea mays* (popcorn) except the apical 1.5 to 2^{mm}, fifteen positive curves and sixteen straight roots resulted. Unfortunately the periods of the experiments for this plant were only from 4 to 8 hours. Had they all extended to 12 hours there would doubtless have been a much larger proportion of curves. The absence of any negative curves, however, shows that the curves obtained were really rheotropic. The apical 0.5 to 1.5^{mm} of the root of *Raphanus sativus* exposed to the water stream by the same method as used with *Zea mays* (popcorn) gave thirty positive curves and nine straight roots in a total of thirty-nine seedlings. In two of these experiments there was never more than 1^{mm} of root tip exposed to the current, yet even in this case more than half the roots became positive. *It may be claimed, therefore, that the rheotropic sensitiveness of the very apex of the root has been demonstrated.*

That the root of *Vicia sativa* is rheotropically sensitive throughout its elongating zone was indicated, but not demonstrated by the experiments of Juel (*l. c.*). He employed too few seedlings, especially in the case in which 7 to 8^{mm} of the apex of the root were covered with collodion caps, where he used only six roots and obtained only two reliable curves. In my experiments forty-eight seedlings of *Raphanus sativus* had their apical 10^{mm} covered with glass tubes, and thirty-four gave positive response in a water stream. In another series with the same species, twenty-three roots had their apical 15^{mm} of the root covered, and ten gave positive curves. When, however, nineteen seedlings of Raphanus had 20^{mm} of the apex of their roots covered, only seven very weak positive curves appeared, while there were four weak negative curves, and eight straight roots. *It may be said, therefore, that the roots of Raphanus sativus are rheotropically sensitive for more than* 15^{mm} *of their apex*, but

scarcely, if at all, sensitive beyond 20^{mm} of their apex. In preceding pages it has been shown that *the rheotropic sensitiveness decreases proximally from the limit of the elongating zone.* Since the elongating zone in *Raphanus sativus* has been shown to extend less than 6^{mm} from the apex of the root, *we have in this plant, and probably in other rheotropic plants also, a sensory area ten or more millimeters distant from the limit of the elongating zone, and therefore a transmission of stimulus through a distance of twelve or more millimeters from tissue that has ceased to elongate.*

Rheotropism is not confined to the primary root. Berg (*l. c.*) states that he observed it in the secondary roots of eight species of plants, while it was absent in one species. My tests extended to four species. Putting Berg's results and mine together, eleven species with both primary and secondary roots have been tested for the rheotropism of secondary roots. Of these eleven species, eight have shown themselves positive in both primary and secondary roots, two have shown themselves neutral in both orders of roots, and one (*Tropaeolum majus*) was found sensitive in both orders by Berg, but feebly sensitive in the primary and neutral in the secondary roots by me. Berg makes no statement as to relative sensitiveness of primary and secondary roots. In my experiments the secondary roots of *Fagopyrum esculentum* were less sensitive than the primary, but the secondary and tertiary roots of *Zea mays* (yellow dent) were more sensitive than the primary. *One may conclude at least that the secondary roots are sensitive or insensitive according to the sensitiveness or insensitiveness of the primary root.*

All the experiments of former investigators of rheotropism have been carried on with seedlings. In my study the roots of older plants have been tested in five species. The seedlings of four of these species had proved themselves rheotropic, and the roots of the same species a month old were found rheotropic also. In the case of the fifth species neither the roots of the seedlings nor of the older plants were sensitive. *As far as the study has extended, therefore, it has been found that rheotropism is neither gained nor lost in the development of a plant from seedling to near maturity.*

As to the nature of the rheotropic stimulus, there is no direct evidence. I still incline to the notion of pressure, as expressed in my paper before the American Association for the Advancement of Science in 1896. As yet, however, no one has demonstrated in the roots of plants any kind of a response to pressure.

II. TABULATION OF SPECIES EMPLOYED AND THEIR RHEOTROPIC BEHAVIOR.

Family	Species	Rheotropic behavior
Gramineae..........	Zea mays L. Yellow dent...........	Feebly sensitive
	" " Sweet..................	Feebly sensitive
	" " Popcorn.................	Highly sensitive
	Triticum vulgare Vill..............	Feebly sensitive
	Hordeum vulgare L................	Highly sensitive
	Secale cereale L.	Highly sensitive
	Avena sativa L....................	Highly sensitive
Hydrocharitaceae.....	Elodea canadensis Michx...........	Insensitive
Naiadaceae	Potamogeton perfoliatus L.	Insensitive
Liliaceae	Allium cepa L. Bulb...............	Insensitive
	" " Seedlings...........	Insensitive
Ranunculaceae	Ranunculus aquatilis L.............	Insensitive
Cupuliferae	Quercus alba L....................	Insensitive
Cucurbitaceae.......	Cucurbita pepo L..................	Insensitive
	Citrullus vulgaris Schrad...........	Insensitive
Cruciferae	Brassica alba Boiss................	Highly sensitive
	Brassica nigra Koch................	Highly sensitive
	Brassica campestris L..............	Highly sensitive
	Brassica oleracea L................	Highly sensitive
	Raphanus sativus L................	Highly sensitive
	Nasturtium officinale R. Br..........	Insensitive
Geraniaceae	Tropaeolum majus L...............	Feebly sensitive
Polygonaceae	Fagopyrum esculentum Moench.....	Highly sensitive
Euphorbiaceae	Ricinus communis L................	Insensitive
Leguminosae........	Vicia faba L.......................	Feebly sensitive
	Vicia sativa L.....................	Fairly sensitive
	Lupinus albus L...................	Fairly sensitive
	Phaseolus vulgaris L...............	Insensitive
	Phaseolus lunatus L...............	Insensitive
	Phaseolus multiflorus Willd..........	Insensitive
	Pisum sativum L....................	Fairly sensitive
	Glycine hispida Maxim.............	Insensitive
	Dolichos lablab L..................	Insensitive
	Lathyrus odoratus L......	Fairly sensitive
Compositae	Helianthus annuus L...............	Fairly sensitive

In addition to ten of the species in the foregoing table, Berg tested *Lupinus luteus* L. and *Fagopyrum tataricum* Gaertn., both of which he found sensitive.

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PARTHENOGENESIS IN THALICTRUM PURPURASCENS.

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY. XXXV.

JAMES BERTRAM OVERTON.

(WITH PLATES XII-XIII)

INTRODUCTORY.

THE well known experiments of Loeb in inducing by artificial methods the segmentation of the unfertilized eggs of some of the lower animals, and the formation of embryos, suggested similar experiments with the eggs of plants. Experiments of like nature have been made upon lower plants, but the eggs of the higher plants do not lend themselves readily to experiment. Nevertheless, it was concluded to make the attempt with some angiosperm. It seemed best to select a dioecious plant, and one suspected of exhibiting parthenogenesis. The clue was furnished in a paper read by David F. Day at the Buffalo meeting of the American Association for the Advancement of Science in 1896. It was entitled "Parthenogenesis in *Thalictrum Fendleri*," and the following abstract was published in the Botanical Gazette (**22**: 241 S 1896):

> In 1883 a seedling of *T. Fendleri* was sent home from Colorado for cultivation. In late May it flowered and proved to be pistillate. About the last of August it presented abundant and good seed, although no staminate plants of any species of Thalictrum were in the neighborhood. The seeds were planted and yielded abundantly staminate and pistillate plants. Staminate plants have been artificially prevented from maturing flowers almost every year since. At least eight times in thirteen years the pistillate plants have produced good seed in abundance. Plants were sent to Meehan, Missouri Botanical Gardens, and Orpet of S. Lancaster, Mass., and all report in 1896 perfect seed from pistillate plants. This seems to be a clear case of parthenogenesis. *T. dioicum* does not show a similar habit.

This might have been a case of parthenogenesis or of vegetative apogamy, not to be determined without careful morpho-

logical study. In any event, it suggested a species for study, and the allied *T. purpurascens*, abundant in the vacant lots in Chicago, was selected.

The work was begun early in the summer of 1900 and carried on at the Hull Botanical Laboratory of the University of Chicago. Acknowledgments are due to Professor John M. Coulter for much suggestive advice during the prosecution of the work, and also to Dr. Charles J. Chamberlain and Dr. Burton E. Livingston for assistance in collection, technique, and interpretation. Mr. Andrew C. Moore, now of the University of South Carolina, also gave much assistance in collecting material.

METHODS.

A compound microscope was taken into the field in order to determine whether the flowers were pistillate or staminate. Only such plants as were found by this means to be pistillate were used. In fact, the flowers were all too young to be determined in any other way. A dozen such pistillate plants were isolated in the greenhouse of the laboratory, nine of which survived. The plants were numbered, and watered with solutions of various salts. This mode of treatment was kept up until after the time fertilization would have taken place normally and until the stigmas ceased to be receptive. Each week some of the developing flowers were killed in a one per cent. solution of chrom-acetic acid and kept in 70 per cent. alcohol for further study. In the autumn these plants were dried and their rootstocks preserved in pots over winter. These were forced about the first of April, and all produced abundant pistillate flowers long before those out of doors had blossomed. This made it certain that pollination did not occur, as these flowers were mature and their stigmas had ceased to be receptive long before those out of doors had even begun to bloom, much less to produce pollen.

Fifteen or sixteen other pistillate plants were chosen at the same time by the same means and transplanted into the garden of the laboratory. The inflorescences of these were securely covered or capped with paper bags so as to prevent pollination.

The flowers developed in these bags from the time the pistils had to be determined by means of the microscope until the seeds matured. Each week a head was removed, the flowers being preserved as above for future study.

All plants that survived under all the conditions, in the greenhouse, or in the garden, or as rootstocks, produced abundant and fully developed seeds. Of course in such a case it seemed unlikely that the treatment with the solutions produced the effect. Therefore the problem resolved itself into an investigation of the embryos, to determine whether or not there was parthenogenesis, the embryo developing from the unfertilized egg, or vegetative apogamy. Abundant and good material had been preserved, which it was hoped would show all stages required to answer this question. The material after fixing and killing was brought gradually into 70 per cent. alcohol and there kept until used. The xylol-paraffin method was used entirely, and sections were cut with a microtome from 5–15μ thick as the case required. Sections were stained with Delafield's haematoxylin and also with Flemming's safranin, gentian-violet, and orange method. All drawings were made with a Zeiss camera and a $\frac{1}{12}$ Bausch and Lomb oil immersion.

RESULTS.

It is not the purpose of this paper to describe the development of the megaspore in detail, for it differs in no way from that usual among angiosperms. In the very young ovule the archesporial cell is distinguishable (*fig. 1*, *a*), later enlarging (*fig. 2*), and dividing unequally to form the so-called tapetal cell (*fig. 3*, *t*) and the larger primary sporogenous cell (*fig. 3*, *s*). The tapetal cell may or may not divide further. *Fig. 4* shows a division. The primary sporogenous cell gives rise to the usual row of four megaspores (*fig. 5*), the innermost spore of the tetrad functioning (*fig. 5*, *fm*).

The megaspore germinates in the usual way, enlarging at the expense of the surrounding cells until it occupies a large part of the nucellus (*fig*, *6*), and the nuclear divisions resulting in the usual groups of nuclei at each extremity of the sac.

Fusion of the polar nuclei takes place immediately, and this seems to act as a stimulus for the rapid enlargement of the sac (*fig. 6, pp.*). The fusion nucleus also enlarges very rapidly and staining shows it to be rich in chromatin. It may lie near the oosphere, or in the center of the sac, or close to the antipodals (*figs. 7, 8, 11*). It is always surrounded by abundant cytoplasm, which is connected by strands to the mass about the egg and the antipodals, and often contains numerous nucleoli. It remains very large and active while the sac is enlarging to four or five times the size it had when the polar nuclei fused (*fig. 11*).

The synergids present the usual appearance. They are vacuolated at the lower end, with the nuclei above the vacuoles, the upper end presenting a striated appearance (*fig. 11 syn*).

The oosphere is not much longer and very often shorter than the synergids (*o* in *figs. 6, 7, 8, 11*), and is never very rich in stainable material, the nucleus taking only slightly the stain taken by the definitive nucleus very heavily. There is abundant cytoplasm surrounding the egg in all cases, with strands radiating to the mass about the definitive nucleus, as above mentioned. Although the egg is usually shorter than the synergids at the time of fusion of the polar nuclei (*figs. 6, 7, o*), after this fusion, while the sac is greatly enlarging in all directions (*fig. 11*) especially in length, the egg begins to reach down into the sac far below the synergids, becoming highly vacuolated and staining very feebly (*figs. 3, 7, 10, a, 11, v*), appearing to reach its fullest development just at the time the free endosperm nuclei become parietally placed.

One of the most notable features of the sac is the remarkably large size of the antipodal cells, which often reach almost to the center of the sac, their nuclei multiplying by fragmentation (*figs. 7, 8, 11*).

As before mentioned, the definitive nucleus is remarkably large, resting near the egg, or near the antipodals, but more frequently centrally placed in the sac. Free nuclear division takes place very rapidly, and in no instance did division of the egg take place before division of the endosperm had begun. This

free nuclear division is so rapid as to produce in a remarkably short time a great number of nuclei, during which the sac enlarges very rapidly in all directions. It may be well to note here that the first division of the egg takes place when the free nuclei become parietally placed, lining the whole sac. Coulter found in species of Ranunculus "occasional evidence of endosperm-formation before the fusion of gametes, and even before the entrance of the pollen-tube into the cavity of the sac." In my examination of normal material of *T. purpurascens* I have been unable to find any stages that show segmentation of the egg before the definitive nucleus divides, in all cases free nuclear division having begun before fertilization. In the material that I know to be parthenogenetic the free nuclear division began without any stimulus from fertilization, and always before the egg divides. Undoubtedly fertilization, when it takes place, may exert an influence upon the definitive nucleus, as it is known to do upon other adjacent structures, but it is not absolutely necessary to its division. The parietal placing of the free endosperm nuclei is followed by the formation of cell walls, and the endosperm gradually fills the cavity of the sac.

As described above, the egg becomes elongated far below the synergids, and there seems to be a great lack of stainable material in both nucleus and cytoplasm. In every case observed the cytoplasm of the sac was very dense about the egg, except the zone immediately in contact with it. This layer appears to be of a different consistency and stains very little, much resembling the zone of broken-down endosperm tissue so frequently found surrounding an embryo in the seed. It suggests that the egg is giving off an enzyme that digests the adjacent cytoplasm.

No attempt was made to trace in detail the development of this embryo, as that was not the purpose of the work. Without fertilization the first division occurs, and is transverse (*fig. 12*) as usual. The next division is also transverse, and a row of three or four cells is formed, after which a longitudinal division takes place in the terminal cell, differentiating the embryo-proper from the suspensor. The persistence of the synergids is very

noticeable, and this might be expected, since no pollen tube has entered the sac to draw upon them for food supply. The synergids in the normal material were not evident in all cases after the embryo had begun to develop. After the first longitudinal division of the embryo, similar divisions may take place in the suspensor, resulting in a massive, rather short, much twisted, thick-walled suspensor (*fig. 15, su*). Finally, the parthenogenetic embryo becomes morphologically well developed, showing dermatogen, periblem, and plerome, exactly as in normal embryos. In fact no difference can be seen between the perfectly normal embryo and this parthenogenetically formed one (*fig. 16*). The endosperm continues to develop until it entirely fills the cavity of the sac and lies in a mass about the embryo. Abundant seed is produced by *T. purpurascens*, both from free and isolated pistillate plants. The percentage of seed produced in the parthenogenetic material is quite as great as under perfectly normal conditions in the field.

GENERAL DISCUSSION.

There have been described only two other cases of true parthenogenesis among spermatophytes. In 1898 Juel[1] described parthenogenesis in *Antennaria alpina*. No figures were given, and we have to depend upon his text for the facts. In 1876 Kerner[2] had noticed that plants of *A. alpina* were matured in the Botanical Garden at Innsbruck when no staminate flowers were present. It is the rule for plants of *A. alpina* to have only pistillate flowers, while staminate flowers are exceedingly rare, and are not necessary to the propagation of the species. The pollen grains are not fully developed, or very seldom so, even when there are staminate flowers present, being functionless according to Juel. Juel maintained that Kerner did not find parthenogenesis in the true sense of the word, but only seed-development without fertilization. A critical study of *A. dioica* showed that it behaved

[1] Parthenogenesis bei *Antennaria alpina*. Bot. Centralbl. 74:369. 1898.

[2] Parthenogenesis einer angiospermen Pflanze. Sitzungsb. Acad. Wiss. Wien 74:469. 1876.

normally, fertilization occurring and the embryo coming from a fertilized egg. In *A. alpina*, however, he found that the egg forms an embryo without fertilization. In this case the polar nuclei never fuse or even approach each other, dividing independently to form the endosperm, which is finally absorbed by the embryo. Juel explains the behavior of the polar nuclei on the ground that one of the polar nuclei and the egg have arisen through the same nuclear division, and as the egg nucleus is able to divide without fertilization, the polar nuclei can divide without fusion. Even if this explains the division of the upper polar nucleus, it does not apply to the lower one. Juel did not follow the chromosome reduction at that time, but later investigated it in *A. alpina.* He found[3] that tetrad formation does not take place, while in *A. dioica* there is the usual row of four. Juel concludes that there is no reduction in *Antennaria alpina*, so that the nuclei of the parthenogenetic embryo contain the normal number of chromosomes.

In 1895 Murbeck[4] suggested that certain species of Alchemilla are parthenogenetic. During the summers of 1892 and 1893 he observed in the neighborhood of Stockholm a form of Alchemilla which seemed to be intermediate between two forms that grew in the same locality. In order to determine whether the intermediate form was a hybrid, he made a comparative study of the reproductive power, and later of the formation of pollen. In all three forms he found the pollen impotent, and yet all set seed. Two other forms, growing in the Royal Botanical Garden of the Academy of Science of Stockholm, behaved likewise. Material was also collected from different parts of Europe in 1894 and 1895. Murbeck found that *A. alpina*, *A. sericata*, *A. pubescens*, and *A. vestita* produced no pollen whatever; that *A. acutangula*, *A. subcrenata*, and *A. alpestris* sometimes developed pollen, but the amount was very much out of proportion to the number of seeds produced. Of the great number of species

[3] Botaniska Notiser 102. 1900.

[4] Skandinaviska former af Alchemilla vulgaris. Botaniska Notiser 265 (Fussnote). 1895.

examined only the oriental species *A. speciosa* showed normal pollen. He came to the conclusion, after mixing the plants and finding no variations in the species, that the pollen sparingly produced by some forms had no fertilizing power. These results he published in 1897,[5] with the statement that he hoped later to discover whether there is actual parthenogenesis or whether the embryo arises from the nucellar tissue. With this purpose in view, Murbeck examined numerous species of the section EUALCHEMILLA, but his important results are mainly derived from *A. alpina*. He has traced every stage of development from the archesporial cell to the formation of the embryo, and published his results in 1901.[6] He found a central mass of archesporial cells, and that the numerous primary sporogenous cells may each give rise to a row of three or four megaspores, one or all of which may give rise to embryo sacs. In regard to chromosome reduction, he observed in a pollen mother-cell of *A. arvensis* that the reduction number was 16, but he claims that in parthenogenetic species there is no reduction of chromosomes. He shows that there is no direct relation between endosperm-formation and embryo-formation. A noticeable fact is that before the egg divides the whole egg-apparatus stretches far into the sac, and then division takes place without fertilization, a perfect embryo being developed. The first division takes place while the flower is still in developmental stages. Murbeck also found two embryos in a single sac, one developed from the egg and the other from a synergid.

The two cases described by Juel and Murbeck, and *Thalictrum purpurascens*, described in this paper, are the only cases of true parthenogenesis thus far recorded among seed-plants, though of course the phenomenon is common enough among certain lower plants. The so-called cases of parthenogenesis among seed-plants, as *Coelobogyne ilicifolia*, *Mercurialis annua*,

[5] Om vegetativ embryobilding hos flertalet Alchemillor och den förklaring öfver formbeständigheten inom slägtet som densamma innebär. Botaniska Notiser 273. 1897.

[6] Parthenogenetische Embryobilding in der Gattung Alchemilla. Lunds Universitets Årsskrift 36 : 1–40. *6 pls.* 1901.

etc., were long ago shown by Strasburger[7] to be cases of vegetative apogamy.

In *Balanophora elongata* Treub[8] has shown that there is no fertilization, but that a "pseud-embryo" is developed apogamously from the endosperm. We see no reason why this whole "pseud-embryo" structure with the endosperm in which it develops may not be considered an embryo developed apogamously from the micropylar polar nucleus, which later organizes a growing point as does a normal embryo. Lotsy[9] found exactly the same state of affairs in *Balanophora globosa*, a species with no staminate flowers. In the case of *Rhopalocnemis phalloides*, which Lotsy[10] also recently investigated, no seeds are ever produced. He could not discover a pollen tube, nor could he induce pollen tubes to develop by artificial pollination. In a few cases he secured some seeds, but was certain the embryos had developed from the eggs, probably after fertilization.

It is shown that an embryo may be produced from any cell of the embryo sac, and in this sense they may all be regarded as potential eggs. But since the same fact is true of cells of the nucellus, the statement has little significance. Experimental work done within the last five or six years upon the eggs of marine animals has thrown some light upon the causes of the segmentation of unfertilized eggs. Mathews[11] showed that the unfertilized eggs of star-fish could be made to extrude polar bodies by violent shaking. Morgan[12] found that eggs placed in sea water of a higher osmotic pressure than normal sea water divided upon being returned to the latter. Mead[13] showed that

[7] Ueber Polyembryonie. Jenaisch. Zeitschr. Naturwiss. **12** : 659. 1878.

[8] L'organe femelle et l'apogamie du *Balanophora elongata*. Ann. Jard. Bot. Buitenzorg **15** : 1–22. 1898.

[9] Balanophora globoso. Ann. Jard. Bot. Buitenzorg **16** : 26–29. 1899.

[10] Rhopalocnemis phalloides Jungh., etc. Ann. Jard. Bot. Buitenzorg II. **2** : 73–101. 1900.

[11] Anat. Anz. **9** : 150. 1894.

[12] Archiv. für Entwicklungs. mechanik der Organismus **8** : 448. 1899.

[13] Lectures at Woods Hole. 1898.

eggs of Chaetopterus could be made to divide by placing them in sea water to which KCl had been added. Morgan[14] confirmed the results obtained by Hertwig as to the action of strychnin sulfate. He expressed the opinion that eggs are in a state of unstable equilibrium, and would react to various stimuli by division just as other cells would react in other ways to the same stimuli. Loeb[15] found that exposure of eggs of Arbacia for a short period to sea water to which alkali or acid had been added induced cell division. He has arrived at certain conclusions by further experiments upon the unfertilized eggs of echinoderms.[16] He has shown that such eggs can be made to develop into normal embryonic forms through a certain increase in the osmotic pressure, produced either by electrolytes or non-electrolytes. He suggests the probability that parthenogenetic development is caused by loss of a certain amount of water from the egg. Mathews[17] found that karyokinetic divisions in the eggs of Arbacia could be induced by the lack of oxygen, by heat, by exposure to ether, alcohol, and chloroform. Loeb[18] also produced artificial parthenogenesis in eggs of other animals than echinoderms by increasing the osmotic pressure, as Chaetopterus, etc. His experiments have convinced him that the essential feature in increasing the osmotic pressure of the surrounding medium is a loss of water on the part of the egg. He also states that if we assume the spermatozoön starts the development of the egg in the same way as in the case of artificial parthenogenesis, it must follow that it possesses more salts of a higher osmotic pressure than the egg. He has also suggested that the spermatozoön may bring about the same condition in the egg as is produced by loss of water.

These experiments suggest an explanation of parthenogenesis as observed in Thalictrum. The egg is invested by a dense sheath of cytoplasm, and that there is some reaction between

[14] Science N. S. 2 : 176. 1899.

[15] Jour. Phys. 3 : 447. 1899.

[16] Further experiments on artificial parthenogenesis and the nature of the process of fertilization. Jour. Phys. 4 : 178. 1900.

[17] Jour. Phys. 4 : 341. 1900.

[18] Science N. S. 2 : 70. 1900.

the two is evidenced by the change in the structure of the cytoplasmic layer immediately in contact with the egg. Whether or not the egg excretes an enzyme that digests the cytoplasm is a matter of detail. The fact remains that physical changes are evident in the cytoplasm in contact with the egg, which then divides. Such changes may well vary the osmotic pressure within the egg, and lead to nuclear division as shown by the experiments referred to above.

While *Thalictrum purpurascens* is parthenogenetic under artificial conditions, parthenogenesis also takes place in plants grown under perfectly natural conditions if pollination be prevented, as is shown by plants setting seed in the gardens when the flowers are covered with paper bags. All such plants showed quite as many seeds per plant as those which had been fertilized and grew in the field. Many flowers were cut from natural specimens in order to compare them with the parthenogenetic material. In many cases a pollen tube could be detected, but in far the greater number no such tube or any evidence of a tube having been present could be seen. One can tell by even a casual inspection of the micropyle whether a tube has been present or not. I am led to conclude that many seeds are produced parthenogenetically under normal conditions if for any reason fertilization fails. So far as I could determine, there seems to be no real necessity for pollination in order to propagate the species. The plant is getting towards the habit of complete parthenogenesis, when pollen will become impotent, a condition apparently attained by *Antennaria alpina* and several species of Alchemilla. Even though the number of recorded parthenogenetic genera among dicotyledons be so small, the genera are rather widely distributed. It would seem as if parthenogenesis must be of much more common occurrence among angiosperms than is at present known.

SUMMARY.

1. The development and germination of the megaspore is that usually found among angiosperms.

2. Fusion of the polar nuclei is early, always before fertili-

zation in normal material, and before the division of the egg in parthenogenetic material.

3. Fertilization is not necessary to embryo-development or to endosperm-development.

4. Embryos were produced parthenogenetically under all conditions, and normal material showed the phenomenon to be general in nature.

5. The cytoplasm of the early stages of the sac is closely packed about the egg. Later the egg becomes surrounded by an area much resembling a vacuole, which may affect the osmotic pressure and indicate a withdrawal of water, causing the oosphere to divide.

6. The development of the embryo in parthenogenetic material is the same as found in normal material.

7. Parthenogenesis is becoming fixed in Thalictrum.

ILLINOIS COLLEGE,
Jacksonville, Ill.

EXPLANATION OF PLATES XII AND XIII.

FIG. 1. Section of young ovule showing archesporial cell (*a*).

FIG. 2. The same, showing enlarging archesporial cell (*a*).

FIG. 3. Section of young ovule with integument forming, showing tapetal cell (*t*) and primary sporogenous cell (*s*).

FIG. 4. Anticlinal division of tapetal cell (*t*); the nucleus of the primary sporogenous cell also dividing.

FIG. 5. Young nucellus, showing tapetal cell (*t*), the three functionless megaspores (*m*), and the functional megaspore (*fm*).

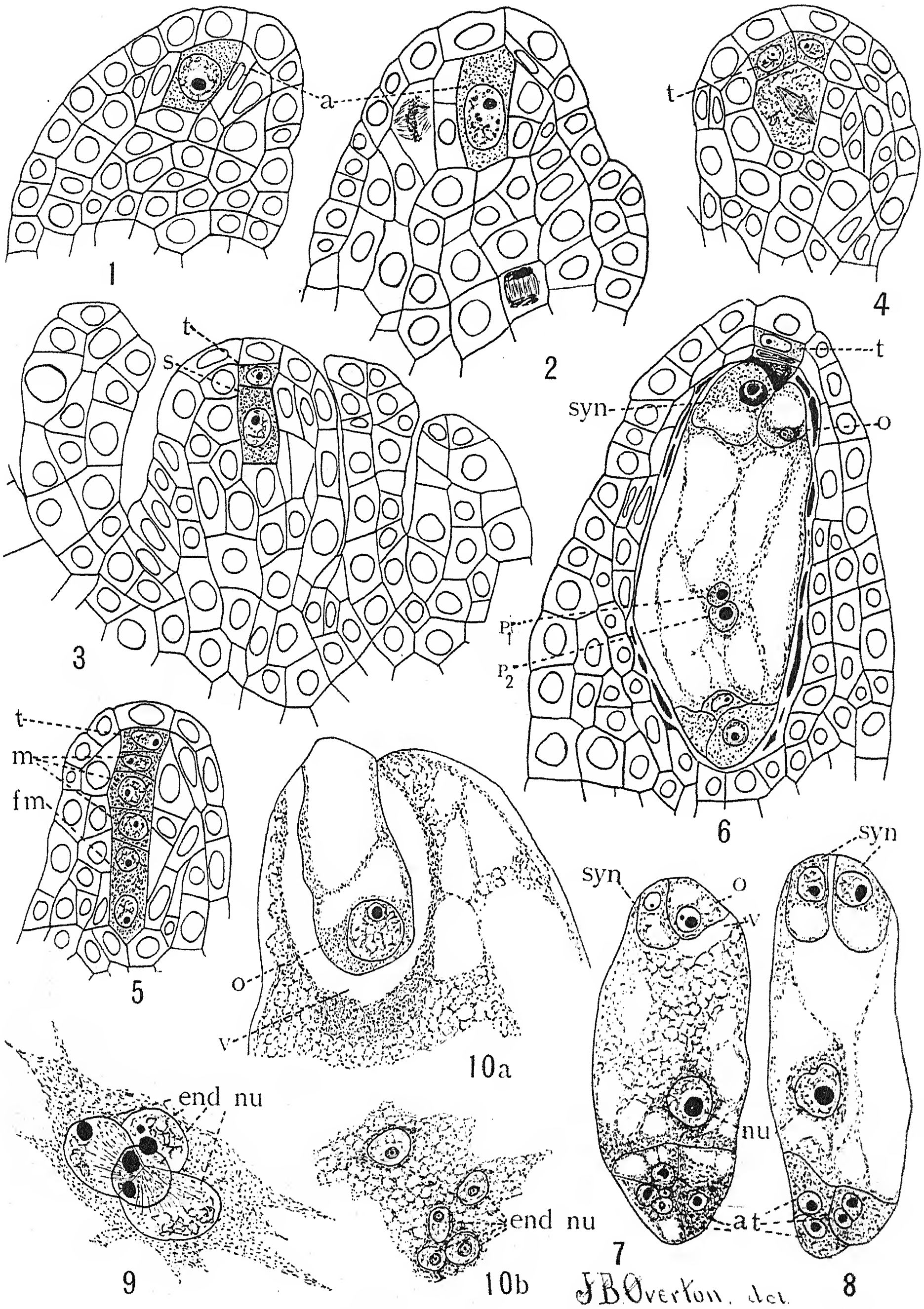
FIG. 6. Young embryo-sac; *syn*, synergid; *o*, oosphere; *t*, tapetal cell, with the three functionless megaspores crowded between it and the embryo-sac; P_1 and P_2, upper and lower polar nuclei fusing.

FIG. 7. Young embryo-sac immediately after fusion of polar nuclei; *o*, oosphere; *v*, area or vacuole about the oosphere; *syn*, synergid; *nu*, definitive nucleus; *at*, antipodals.

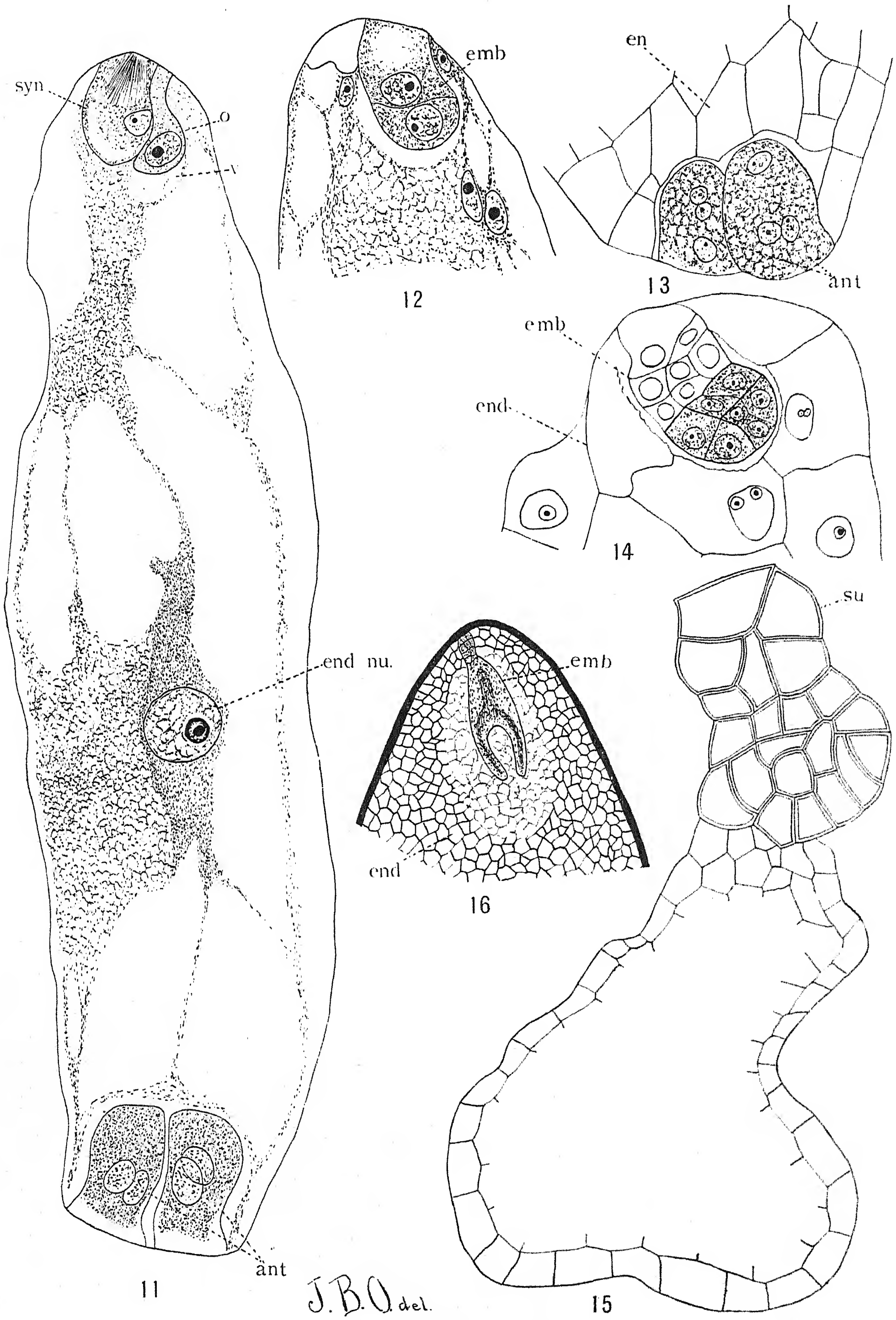
FIG. 8. Same as *fig.* 7, but showing both synergids (*syn*) without the oosphere.

FIG. 9. A group of endosperm nuclei resulting from the first divisions of the definitive nucleus.

FIG. 10*a*. The oosphere (*o*) beginning to extend into the sac, with the vacuole (*v*) surrounding it.



OVERTON on THALICTRUM



OVERTON on THALICTRUM

FIG. 10 *b*. A group of free endosperm nuclei from same sac, showing free endosperm nuclei before egg divides.

FIG. 11. Embryo sac just before the division of the oosphere; *end nu*, large and active definitive nucleus; *syn*, synergid; *o*, oosphere before elongation into the sac; *v*, vacuole forming about the oosphere; *ant*, large multinucleate antipodals.

FIG. 12. Two-celled parthenogenetic embryo (*emb*) with the vacuole about it; a few free endosperm nuclei are seen scattered in the cytoplasm of the sac.

FIG. 13. Antipodals (*ant*) still present when the embryo sac is entirely filled with endosperm cells (*em*).

FIG. 14. A young parthenogenetic embryo (*emb*) at end of suspensor, and surrounded by endosperm cells (*end*).

FIG. 15. A still more advanced parthenogenetic embryo, showing the thick-walled twisted suspensor (*su*).

FIG. 16. Diagrammatic sketch showing general relation of the parthenogenetic embryo (*emb*) to the endosperm (*end*) in the seed.

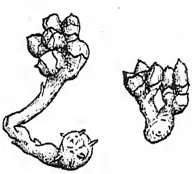
BRIEFER ARTICLES.

SUBTERRANEAN PLANTS OF EPIPHEGUS.

(WITH ONE FIGURE)

HAVING need of *Epiphegus virginiana* in late October, 1900, I sought a piece of beech woods in Holbrook, Massachusetts, where I found the plant growing abundantly in rich, deep humus. It was past the flowering time of this species in the main, but the warm season that year was unusually protracted, and numerous short shoots were being produced from the swollen stem bases, upon which I found flowers and fruit in all stages of development. The flowers borne by these late branches are very small. They are all cleistogamous and invariably give rise to capsules filled with fertile seed.

Occasionally these secondary shoots were observed to be flowering somewhat below the surface of the ground. This fact led to further exploration, and on turning up the mold I found many shoots that for one reason or another had never escaped from the soil. They were as productive of fruit and seed as the aerial branches. Finally, I brought to light a number of whole plants that had come to maturity below the surface. They were buried one or two inches deep, and were dwarf specimens, an inch or less in height. They bore several fruits containing good seed. A life-size figure of two of these plants is given herewith.



Whether this variation is simply physiological and due to tardy germination or lack of nourishment, as seems probable, or is constitutional and inheritable, the case offers an interesting example of a phanerogam leading its existence, and indeed completing its entire cycle of life, underground.—R. G. LEAVITT, *The Ames Botanical Laboratory, North Easton, Massachusetts.*

NOTES OF TRAVEL. VIII.

AMERICAN AUTUMN FOLIAGE IN EUROPE.

AS I TRAVEL through the forests of Arkansas and feast my eyes upon the splendor of their autumn foliage, which is second in beauty

only to such regions as the Berkshire hills, I am reminded of a little discovery I made last October in Bavaria. In visiting the large nursery of the brewing institute of Weihenstephan at Freising near Munich, my attention was attracted by several dashes of bright red color among the generally somber browns and yellows of the autumn foliage. These flashes of color were quite remarkable, even from the distant hill where the institute stands. Upon inquiry I learned that this bright-colored foliage was borne by American and Japanese trees or shrubs, and that the brightest of all was our common American *Quercus rubra*, whose leaves were as deeply colored as I have ever seen them in America. Inspector Steinbock remarked, when I expressed my surprise at their color, that there were in the park near Munich several good-sized trees of the swamp maple (*Acer dasycarpum*) whose leaves regularly colored up in the autumn the brightest wine red. I visited these trees and was gratified to find them of the same dark red which we are accustomed to associate with this species in America. The Japanese species which was so brightly colored at the brewing institute was a species of Berberis, I believe, according to Mr. Steinbock, and its narrow leaves were a dark crimson.

So much has been said about the peculiarities of American and Japanese climate as a cause for the brilliant autumn foliage characteristic of these countries, that I fear we have left out of account the consideration of the species themselves. The matter may have been thoroughly discussed in the horticultural literature, but I know of no experiments bearing on the question. If the European oaks when grown in America show fine or quite different colorings from what they do at home, there the effect of climate must be accepted; but the fact just pointed out, that American oaks and maples color up brilliantly in Europe, points to a possible difference of species.

That the local climatic conditions about Munich are not responsible for the color I discovered on mentioning the matter to Mr. Schattel, of the firm of Vilmorin & Company in Paris. He assured me that in the large arboretum of M. Maurice de Vilmorin the same remarkable fact had been observed, and that certain of the American oaks and maples there were most brilliantly colored in autumn. One cannot fail to be struck in such wonderful parks as those of Compeign in France, the Thiergarten of Potsdam in Prussia, or the royal palace grounds in Munich, by the lack of those gay colors in the landscape that give to our autumn so large a share of its peculiar charm. A few

judiciously planted American oaks or maples in these parks would give to the effect just those touches of color that to an American eye seem lacking to make perfect an autumn afternoon stroll.

There is a large field for the study of autumn foliage in Europe and in this country. Individual peculiarities ought to be studied and trees that can be propagated asexually chosen from the thousands of seedlings in the parks. The physiological conditions which produce these colorations will be most interesting, and the effects of hybridization of highly coloring species may be something phenomenal. With the growing passion for ornamentals this feature cannot fail long to attract serious attention, and it would be an easy thing to carry on some international experiments, introducing into Europe quantities of our gorgeously coloring species.—DAVID G. FAIRCHILD, *Department of Agriculture, Washington, D. C.*

A NEW HELIOTROPIUM.

THE cosmopolitan *Heliotropium curassavicum* is supposed to be sufficiently well known, and the idea that the name may at present cover more than one species does not seem to be entertained. However, when I saw the plant passing as *H. curassavicum* in southern California, last summer, I was strongly impressed with the idea that it was quite distinct from that of southern New Mexico (Mesilla valley) and northern Mexico (Juarez in Chihuahua), which had been familiar to me for some years past. The latter plant is lower and less robust, with white flowers, which are visited at Juarez by a peculiar bee of the genus Perdita, a strong indication that the plant is really a native of the region.

The Californian plant I described from fresh material gathered at San Pedro in July, as follows: Spreading, about 20^{cm} high, robust, main stems 6^{mm} in diameter, bluish-green; leaves spatulate, the largest about 53^{mm} long and 20 broad; average leaves 27^{mm} long and 9 broad; larger leaves about 1^{mm} thick, smaller 0.5^{mm}. Flowers arranged as in *H. curassavicum;* flowering spikes usually in threes, about 25^{mm} long, elongating fruit to 60^{mm} or more; flowers 7^{mm} diameter, varying in the same spike from 5 to 6-lobed corolla; corolla white, throat deep purple or yellow (both colors on same spike); calyx-lobes lanceolate, equaling the tube of the corolla; corolla more or less purple outside, so that the buds appear purple.

The yellow-eyed flowers are the freshest; probably they later become purple-eyed. This plant goes south along the seacoast, at least to San Diego county. I consulted a number of floras of different parts of the world, and found that the flower of *H. curassavicum* was almost universally considered to be white. Unfortunately, in drying the plant turns black, and I have never been able to prepare really satisfactory herbarium specimens. It may be on account of this difficulty that the several species (if such there are) have not been discriminated. If botanists resident where presumed *H. curassavicum* grows will carefully note the characters of the living plants, perhaps we may in time reach the solution of the matter.

Since writing the above note I have obtained fresh material of the New Mexico species at Albuquerque, still in flower December 3, 1901. Renewed comparisons make it evident that this inland form requires a distinctive name, as follows:

Heliotropium xerophilum, n. sp.— Flowers 3.5^{mm} in diameter; corolla 5-lobed, white (not turning violet), tinged with yellow within; lobes small, rounded; flowering spikes only about 20^{mm} long; calyx lobes narrow, pointed; fruit globular, 4-lobed, with distinct sutures, lobes rounded; leaves obtuse-lanceolate, about 30^{mm} long and 7 broad.—T. D. A. Cockerell, *East Las Vegas, New Mexico.*

CURRENT LITERATURE.

BOOK REVIEWS.

The physiology of plants.

Another part of the new edition of Pfeffer's text-book of plant physiology [1] has recently been published. This is the first part of Vol. II, which deals with energy exchanges in the plant. The first volume appeared in 1897.[2] This part embraces ten chapters, headed as follows: I. Movement of growth; II. Mechanism of growth; III. Growth and cell division; IV. Elasticity and cohesion in the plant body; V. Tissue tensions; VI. Influence of external conditions upon growth; VII. Internal causes of specific configuration; VIII. Variation and heredity; IX. Rhythm in the processes of growth; and X. Power of resistance to extreme conditions. The subject-matter has been largely rewritten, so that the present edition is quite distinct from the former one. The treatment is divided into topics which are numbered consecutively throughout the volume, regardless of chapters.

Each chapter contains a full and critical treatment of the present condition of the subject, together with a historical résumé of the contributions which have been most important in bringing our knowledge to its present state. The literature is pretty well brought up to the date of publication, and citations by footnotes are very numerous. The practical value of these citations would have been much enhanced had the use of the sign *l. c.* been avoided by an occasional repetition, and had a more general uniformity in the form of citation been observed; here and there appears even that *bête noire* of the student of scientific literature, a reference by page to a repaged separate. Besides this comprehensive treatment of our present knowledge, a discussion of the subject from the theoretical side is also presented. As is quite usual with this author, the discussion often goes so far as to point out not only promising lines for future research, but also the possible and probable results of such work.

If there can be noted in the style of the author any change since the appearance of the previous edition, it is in the direction of greater clearness and directness of statement. The curiously involved sentences, which have

[1] PFEFFER, W., Pflanzenphysiologie, ein Handbuch der Lehre von Stoffwechsel und Kraftwechsel in der Pflanze. Zweite völlig umgearbeitete Auflage. II Band: Kraftwechsel. 1 Hälfte. 8vo, pp. 1–353. *figs. 31.* Leipzig: Wilhelm Engelmann. 1901.

[2] See review in BOT. GAZ. 25: 132. 1898.

made Pfeffer one of the most difficult writers for the foreign student, are still in evidence, but, if we judge rightly, not so emphatically in evidence as heretofore. A tendency to avoid terms which serve only to cover up our ignorance, and an attitude of mind which seeks for explanations of physiological phenomena on physical and chemical grounds, is somewhat more pronounced here than in the previous edition. A feeling of admiration and wonder must be aroused in every reader of this volume by the exceedingly broad and familiar grasp of the whole subject that is shown by the author. There seems to be no corner of the realm of physiology into which the acuteness of Dr. Pfeffer's intellect has not allowed him to find his way. This seems to us to be the strongest among the many good qualities possessed by the book, but coupled with it — perhaps necessitated by it — is a quality which is surely destined to cause much dissatisfaction and weariness of the flesh on the part of the student. We refer to the numerous cross references found on nearly every page. To get the author's whole view of any subject one must at length read a good part of the volume.

English readers will hope for the speedy appearance of a translation of this book into their own tongue, for it will surely be from now on the standard reference on the physiology of growth and irritability. All students of this subject will await with impatience the publication of the rest of the volume. — BURTON E. LIVINGSTON.

Enzymes and their applications.

IN 1898 Dr. Jean Effront,[3] of Brussels, published the first volume of an important work upon enzymes and their industrial applications. That work has recently been translated by Professor Prescott, of the Massachusetts Institute of Technology, with the desire "to make available in English the valuable material of the original French work." This volume is devoted to the enzymes which act upon carbohydrates, and to theoxidases. In addition to these, however, it includes a discussion of the glucoside and glyceride enzymes. As only one chapter is devoted to them and one to the oxidases, it will be seen that the greater part of the work is devoted to the carbohydrate enzymes.

Throughout the book the emphasis upon the industrial relations of these substances is very strong. For example, chapter 11 is devoted to the discussion of chemical transformations which accompany germination, the methods of malting, sorting, steeping, germination, and brewing. Chapter 12 is devoted to the rôle of amylase in the brewery; chapter 13 to the manufacture of maltase; chapter 14 to the fermentations which occur in bread

[3] EFFRONT, JEAN, Enzymes and their applications. Translated by Samuel C. Prescott. Vol. I: The enzymes of the carbohydrates. The oxidases. pp. xi + 322. New York: John Wiley & Son. London: Chapman & Hall. 1902. $3.00.

making; and chapter 15 to the rôle of amylase in the distillery. Much attention is also devoted to methods of determining the activity of enzymes, to which Effront himself has contributed greatly, as indeed he has to the whole subject.

Three enzymes are considered in great detail, namely, sucrase (invertase), amylase (diastase), and maltase. The most important industrial applications of maltase seem to be in the manufacture of various oriental beverages.

In several inductory chapters the author discusses the general properties, the mode of action, and the individuality of enzymes. For the general reader or the physiologist these chapters will be found the most useful. The translator adheres to the author's use of the term diastase in its general sense as a synonym of enzyme. In view of the very wide application of the word diastase to a particular group of enzymes this usage may lead to confusion. In general the translation is satisfactory, though the choice of words is not always happy, and the paragraphing might have been greatly improved upon. At the close of each chapter there is a bibliography. The incompleteness of the citations and the diverse forms used will be a source of annoyance to anyone attempting to look up references. The translator could have done good service to English readers by adopting some consistent plan of citation and supplementing the author's bibliographical work.

This book will be certain of comparison with Green's recent work on the *Soluble ferments and fermentation.* The two are written from a wholly different standpoint; in Green's work the industrial applications are only incidentally touched upon, but in those portions where comparison is possible it will hardly be to the advantage of the Effront book. The latter produces an impression of fragmentariness and incompleteness, and there is a lack of finish, all of which leave the reader without a clear-cut impression. This is no doubt due in part to the incompleteness of the subject, for in reality much remains to be discovered regarding these bodies, but part of the result named must be ascribed to the work of the author and translator.

The book, however, will be extremely useful to schools and individuals concerned with the industrial processes of baking, malting, brewing, distilling, etc., in which fermentation plays so important a part.—C. R. BARNES.

Outlines of botany.[4]

MR. LEAVITT has prepared, at the request of the botanical department of Harvard Universty, a text-book of botany for secondary schools, based upon and evidently intended to replace Gray's *Lessons in botany*, which, even in its

[4] LEAVITT, ROBERT GREENLEAF, Outlines of botany, for high-school laboratory and class room, based on Gray's *Lessons in botany*. Prepared at the request of the botanical department of Harvard University. 8vo. pp. 272. *figs. 383.* New York: American Book Company. 1901. Also, combined with *Field, forest and garden botany*.

revised form, is growing less and less acceptable. An endeavor has been made, according to the author's statement, to provide for the "many schools which, having outgrown certain now antiquated methods of teaching botany, find the best of the more recent text-books too difficult and comprehensive for practical use in an elementary course. . . . . The descriptive text follows in the main the sequence of topics of Gray's *Lessons in botany*, and certain parts of that book have been retained. . . . . The writer has felt free to adopt the phraseology of Dr. Gray wherever desired, without quotation marks. . . . . But the greater part of the descriptive text throughout is new, the chapters on cryptogams and on physiology being entirely so."

Mr. Leavitt's own part of the book is fresh, well chosen, and clear, with hardly more than that seemingly irreducible minimum of error to be found in all elementary books. Especially noticeable is the position and character of the laboratory directions, which precede the text on each topic. Besides the section on cryptogams, of fifty-five pages, eighteen pages are devoted to the minute anatomy of flowering plants, and twenty-one to a "brief outline of vegetable physiology." Many of the illustrations are from the admirable drawings made for the *Lessons* and *Structural botany*, and a large number of new ones are introduced, which are both well chosen and well executed.

It will be clear, however, to anyone who considers the laboratory directions that there is much more work laid out, especially in the sections on "cryptogams," than can possibly be accomplished, even in a year of work. Moreover, the laboratory directions for "cryptogams" demand an unusually large amount of material and a thoroughly prepared teacher—the very things which have caused "the best of the more recent text-books to be characterized as too difficult and comprehensive for practical use in an elementary course." That is to say, the teacher must be adequately trained in botany and capable of selecting even from Mr. Leavitt's book. Neither the ignorant nor the slave will be able to use it.

In the absence of any discussion of alternation of generations until the ferns are reached, the relation of the two phases of the liverworts and mosses is left somewhat obscure. Heterospory and the seed habit are touched rather vaguely; indeed, when undertaking to elucidate the "relationship of cryptogams and phanerogams" suppositions are proposed regarding Selaginella which need not he imagined, because they are facts.

Throughout the book the author has retained a great deal of the formal Goethean morphology which characterized the *Lessons* and *Structural botany*. Another survival is to be seen in the maintenance of the division of plants into flowering and flowerless. The author has dropped into smaller type many of the sections which merely define the technical descriptive terms. The chapter treating of the flower, however, is still hardly more than an extended glossary.

We hazard a guess that the demands of the botanical department of Harvard University are more responsible for these features than the judgment of the author. It seems a pity to attempt to galvanize the *Lessons* into a semblance of life again, the more because the book was not only the most popular and widely used, but the most useful text-book of its day; one whose admirable lucidity and directness may well be the envy of the text-book makers of a later generation. It earned for itself an honorable name and a secure place in memory, and should now be allowed to pass, albeit with something of the same regret and sense of loss as at the death of its loved and lamented author. The attempt to combine its method and the modern one is a mistake, as false in theory as it is likely to be futile in practice. Mr. Bergen recently attempted a similar feat in his *Foundations of botany*, offering the old in one hand and all varieties of the new in the other. Authors (perhaps we should say in this case departments of botany) ought to be content to adopt a method which seems to them best, maintain it consistently through the book, and offer it with the other books, written from a similar or a different standpoint, for the intelligent choice of teachers. The other course savors of the commercial rather than the scientific or educational.—C. R. B.

MINOR NOTICES.

EUG. WARMING[5] has published an account of the very peculiar floral structures of certain Brazilian Burmanniaceae discovered by Dr. A. Glaziou, including a description of two new genera (*Glaziocharis* and *Triscyphus*) by Taubet.—J. M. C.

O. A. FARWELL has published a catalogue of the flora (Pteridophytes and Spermatophytes) of Detroit, being a reprint, with additions, from the Eleventh Annual Report of the Commissioners of Parks and Boulevards. It contains a total of 885 species and varieties.—J. M. C.

THE REPORT of the State Botanist of New York for 1900 has just appeared. It contains descriptions of forty-five new species and varieties of fungi. A section on edible fungi describes sixteen forms, three of which are new. Most of the new and edible species are illustrated in the thirteen colored double plates.—J. M. C.

A NEW FASCICLE[6] of Urban's *Symbolae Antillanae* has appeared. The first part (pp. 1–13) is a continuation of the botanical bibliography of the West Indies. The second (pp. 14–158) is a very interesting and apparently complete series of biographical notes of botanists who have visited the West

[5] WARMING, EUG., Sur quelques Burmanniacées recueillies au Bresil par le Dr. A. Glaziou. Bull. Acad. Roy. Sci. Danemark pp. 173–188. *pls. 3–4. figs. 1–6.* 1901.

[6] URBAN, IGNATIUS, Symbolae Antillanae seu fundamenta florae Indiae occidentalis. Vol. III. fasc. I. pp. 1–160. Leipzig: Gebrüder Borntraeger. 1902. *M* 9.

Indies. The last two pages begin the presentation of Piperaceae by C. de Candolle.— J. M. C.

THE THIRD FASCICLE[7] of Halácsy's *Flora of Greece* has appeared, completing the first volume. The previous parts were noticed in this journal for April (p. 290) and December (p. 419). The present part includes from Crassulaceae to Dipsaceae, and closes with a full index of the whole volume. The first fascicle[8] of the second volume has also appeared, containing the Compositae complete, and the beginning of Campanulaceae.— J. M. C.

THE SECOND, THIRD, AND FOURTH FASCICLES of the fifth volume of Thomé's *Flora von Deutschland* have appeared. As stated in a notice of the first fascicle (BOT. GAZ. 33: 71. 1902), this volume deals with cryptogams, excepting pteridophytes, which appeared in the first volume, and is the work of Dr. Walter Migula. The three fascicles received continue the presentation of the mosses, and contain twenty-three plates, eight of which are colored.— J. M. C.

THE SIXTH FASCICLE[9] of Engler's great work on the genera and families of African plants has just appeared, containing the Anonaceae by Engler and Diels. Twenty-two genera are recognized, three of which (*Asteranthe*, *Meiocarpidium*, and *Uvariastrum*) are described as new, and related to the largest genus, *Uvaria*, which includes forty-nine species. Numerous new species are described, and the thirty lithograph plates are models for such illustration.— J. M. C.

THE SECOND EDITION of Dörfler's useful directory of botanists[10] has just been issued. It has the same form and arrangement as the now well-known first edition. This one, however, contains 9,815 addresses, as against 6,455 in the first. The increase, both in number and accuracy, of the addresses in the United States is very marked. Mr. Dörfler renders the botanical world a distinct service in this publication — a service whose drudgery no one can appreciate who has not been through it. As the volume is published at his own risk botanists can reduce this and benefit themselves by purchasing a copy.— C. R. B.

[7] HALÁCSY, E. DE, Conspectus Florae Graecae. Vol. I. fasc. III. pp. 577–825. Leipzig: Wilhelm Engelmann. 1901. *M* 5.

[8] *Idem*. Vol. II. fasc. I. pp. 1–256. 1902. *M* 6.

[9] ENGLER, A., Monographien afrikanischer Pflanzenfamilien und Gattungen. VI. Anonaceae, bearbeitet von A. Engler und L. Diels. 4to. pp. 96. *pls. 30*. Leipzig: Wilhelm Engelmann. 1901. *M* 22.

[10] DÖRFLER, J., Botaniker-Adressbuch, Sammlung von Namen und Adressen der lebenden Botaniker aller Lander, der botanischen Gärten und der die Botanik pflegenden Institute, Gesellschaften und periodischen Publicationen. Zweite, neu bearbeitete und vermehrte Auflage. 8vo, pp. x + 356. Wien: J. Dörfler, III, Barichgasse 36. 1902.

THE PARTS of Engler's *Pflanzenreich* are appearing with remarkable rapidity. The eighth has now been published,[11] containing the Aceraceae (family 163 of the spermatophyte series) by F. Pax. The two genera are *Dipteronia*, a monotypic Chinese genus, and *Acer* with 114 species, 8 of which are new. The monograph is admirable in its painstaking care. Thirteen sections of *Acer* are recognized as follows: I. *Spicata* (30 spp.), II. *Palmata* (6 spp.), III. *Trifoliata* (6 spp.), IV. *Integrifolia* (6 spp.), V. *Indivisa* (9 spp.), VI. *Rubra* (4 spp.), VII. *Negundo* (3 spp.), VIII. *Glabra* (1 sp.), IX. *Platanoidea* (13 spp.), X. *Campestria* (10 spp.), XI. *Macrantha* (12 spp.), XII. *Lithocarpa* (9 spp.), and XIII. *Saccharina* (5 spp.). At the close of each section the geographical distribution is given and also the fossil forms. One map shows the distribution of the thirteen sections, and another the distribution of the fossil groups.—J. M. C.

DR. GY. ISTVANFFI[12] has produced a monumental work in publishing with editorial notes and commentaries the mycological classic of Charles de l'Escluse. This work, whose full title is "Fungorum in Pannonis Observatorum Brevis Historia," was published over 300 years ago, and is the foundation of Hungarian fungology and, to the honor of that country, the first scientific essay on mycology. Istvanffi's paper is a large quarto volume consisting of the following seven parts: (1) an exact reproduction of the *Fungorum Historia*, (2) historical investigations on the origin of the code and the determination of species, (3) biographical notes and an autobiographical sketch of l'Escluse, (4) a synoptical table of species, (5) the correspondence of l'Escluse, (6) catalogue of letters addressed to him, (7) the reproduction of the code with chromolithographic facsimiles of the original water-color sketches. These last are very interesting, and apparently executed with great accuracy. When not presenting original manuscripts Istvanffi has written in Magyar, followed immediately by a translation in French.—B. M. DAVIS.

THE SEVENTH PART of Wiesner's *Die Rohstoffe des Pflanzenreiches*[13] was issued in December last. The seventeenth section on Woods (to which the previous part was devoted) is completed, and the treatment of fibers begun. This section is by the author himself. The anatomical structure, physical and chemical characteristics, and methods of identification by polarization colors, anatomical peculiarities, and microchemical tests are described. A synopsis of fiber plants follows, the phrase being liberally construed as shown by the inclusion of such plants as *Zostera marina* (used in Venice for packing

[11] ENGLER, A., Das Pflanzenreich. Regni vegetabilis conspectus. Heft 8. Aceraceae von F. Pax. pp. 89. Leipzig: Wilhelm Engelmann. 1902. *M* 5.

[12] ISTVANFFI, Études et Commentaires sur le Code de l'Escluse. Budapest. 1900.

[13] Volume II. pp. 161–320. *figs. 45–75.* Leipzig: Wilhelm Engelmann, 1901. *M.* 5.

glassware), Eriophorum, Salix, and Epilobium (on account of the bristles and coma). The major part of the section, however, is devoted to an account of 43 fibers used in the arts. Only 9 of these are treated in the present part. The eighth part[14] has just appeared, completing the account of the fibers referred to above, and beginning the nineteenth section on subterranean parts. This section is an abstract of a paper prepared by Dr. A. E. v. Vogel, professor of pharmacognosy and pharmacology in the University of Vienna.—C. R. B.

THE AMOUNT of injury caused by oat smut in Wisconsin in the year 1901 is estimated by Professor R. A. Moore[15] in a recent bulletin to be $6,387,500, estimating the value of a bushel of oats at 35 cents. These figures were obtained as the result of careful estimates of the percentage of smut on 173 farms in 16 counties of the state by the author of the bulletin, and on 124 farms in 28 counties by former students, representing in all observations in 33 counties in the state. The latter's estimates gave an average of 15 per cent. smutted stalks, while the author's calculations, made ten days later, when the smut had more fully developed, gave 20 per cent. The determination was made by throwing a barrel hoop at random into a field and counting the total number of stalks inclosed and the number of those affected with smut. Several determinations were made in each field. It was found that fields sown with oats that had been soaked, and dried, before sowing for twenty minutes in a solution of one pound of 40 per cent. formalin in fifty gallons of water were entirely free from smut, even when grown beside fields not so treated and accordingly very badly smutted.—ERNST A. BESSEY.

THE FIRST PART of the studies "On the relation of phyllotaxis to mechanical laws," by Arthur H. Church, was noticed in this journal (**32**: 427. 1901), in which the theory was elaborated that "the arrangement of lateral members on a shoot-apex is possibly the expression of the symmetrical or asymmetrical distribution of growth-energy in the growing apex, and in a system for which uniform growth is postulated the appearances are to be mapped in terms of the phenomena of vortex construction, and represented graphically by the same geometrical construction as the lines of equal pressure and flow in circular or spiral vortices respectively." Such conditions of uniform growth do not usually obtain in a growing apex, but their consideration must precede that of varying and diminishing rates of growth. In the second part,[16] now before us, the special cases of phyllotaxis are considered

[14] Volume II. pp. 321–480. *figs. 76–155.* 1902. *M* 5.

[15] MOORE, R. A., Oat smut in Wisconsin—prevalence and method of eradication. Bulletin 91 Wisc. Agr. Expt. Sta. pp. 15, *figs. 2*, F 1902, Madison.

[16] CHURCH, A. H., On the relation of phyllotaxis to mechanical laws. Part II. Asymmetry and Symmetry. pp. 79–211. *pls. 11–25. figs. 36–80.* Oxford: Williams and Norgate. 1902. 5s.

under the following heads: (1) Asymmetry of the normal Fibonacci series, (2) Symmetrical construction, in which the Fibonacci ratios are lost, (3) The special case of "least concentrated" asymmetry, (4) Non-concentrated symmetry, (5) Multijugate systems, and (6) Anomalous systems. Subsequent sections will include the consideration of secondary disturbances in the primary system, the relations of dorsiventral primordia, deductions from the mathematical investigations of the log. spiral systems, and the relation of all these factors to the interpretation of floral structures in the form of floral diagrams.—J. M C.

NOTES FOR STUDENTS.

L. GUIGNARD[17] has discovered "double fertilization" to be a common phenomenon among the Ranunculaceae. To the species he had previously announced in 1900 (*Caltha palustris*, *Ranunculus Flammula*, *Helleborus foetidus*, *Anemone nemorosa*, *Clematis Viticella*, and *Nigella sativa*) he now adds *Nigella Damascena* and *Ranunculus Cymbalaria*. Nawaschin published double fertilization in *Delphinium elatum* two years ago. Double fertilization, therefore, may be regarded as a general habit among Ranunculaceae.—J. M. C.

DAVID GRIFFITHS[18] has described the self-burial of the seeds of *Plantago fastigiata* in the desert region of southern Arizona. His conclusion is that the function of the mucilage is the burial of the seed, and that it is accomplished by the tension set up owing to the contraction of the expanded mucilage which has become firmly attached around its outer and lower edges to the particles of soil into which it has penetrated, resulting in a compacting of the soil immediately below the seed and its coat so as to form a pit into which the seed is forced. The cup-shaped depression is subsequently filled with earth by entirely external influences.—J. M. C.

IN A RECENT CONTRIBUTION[19] from the Gray Herbarium, M. L. Fernald presents the northeastern Carices of the section Hyparrhenae, reaching conclusions very different from those generally accepted by American caricologists. After discussing in considerable detail the more important questions, he presents a synopsis of the forty-one recognized species, including descriptions of four new species and ten new varieties. In the second part of the contribution the variations of some boreal carices are discussed, the species being *C. aquatilis*, *C. pilulifera*, *C. communis*, *C. pennsylvanica*, *C. umbellata*, *C. vaginata*, *C. saltuensis*, and *C. capillaris*.— J. M. C.

[17] Double fécondation chez les Renonculácees. Jour. Botanique **15**: 394-408. *figs. 1–16.* 1901.

[18] A novel seed planter. Bull. Torr. Bot. Club **29**: 164-169. 1902.

[19] FERNALD, M. L., Contributions from the Gray Herbarium of Harvard University. New Series, no. 22. Proc. Amer. Acad. **37**: 447–514. *pls. 1–5.* 1902.

Recently Zimmermann[20] has described some remarkable bacterial nodules which occur in leaves of various Rubiaceae (*Punetta lanceolata*, *P. angustifolia*, *P. indica*, and *Grumilea micrantha*). These nodules consist of masses of spongy parenchyma, the intercellular spaces of which are filled with bacteria. No mention is made whether the bacteria in any way affect the cell walls. The author supposes that the bacteria get into the leaves through a stomate which he finds immediately above each nodule on the upper leaf surface. He made no determination as to a possible causal relation between the nodules and the bacteria, reserving this for further study.—H. v. Schrenk.

F. W. Oliver[21] has described a sporangium of one of the paleozoic ferns, in which an interrupted ring of tracheal elements occurs between the wall and the sporogenous tissue, in the position of a tapetum. The tracheae are rather thin-walled and exhibit well-marked pits of the reticulate type. He is inclined to refer the sporangium to the Botryopterideae, and since these ferns hold certain anatomical relations to the Cycadofilices, this vascular sporangium becomes suggestive of the possible character of the unknown sporangia in the latter group. Of course the occurrence of tracheal elements in the megasporangia of gymnosperms and certain angiosperms is well known.—J. M. C.

A. C. Seward and Elizabeth Dale[22] have described the four species of Dipteris, a genus of eastern Asiatic and East Indian ferns, giving full synonymy; have presented in detail the anatomical structure of *D. conjugata*; in discussing the affinities of the genus as indicated by anatomical characters, and combining these characters with those presented by the sporangium and the form and venation of the fronds, have reached the opinion that Dipteris should be removed from the Polypodiaceae and included in a separate family, of which it represents the solitary surviving type; and have traced the geological history of the genus, which supports the statement that the species of Dipteris are remnants of a family with a wide European distribution during the earlier part of the Mesozoic.—J. M. C.

In studying the embryo of Nymphaea, Henry S. Conard[23] has had occasion to compare it with that of Nelumbo as recently described by H. L. Lyon and noted in this journal (33: 165. 1902.) There is in both the same "spherical embryo" consisting of hundreds of cells, but in Nymphaea there is also a suspensor of three to five cells in linear series. In Nymphaea the

[20] Zimmermann, A., Über Bacterienknoten in den Blättern einiger Rubiaceae. Jahrb. Wiss. Bot. 37: 1. *figs. 9*. 1901.

[21] On a vascular sporangium from the Stephanian of Grand 'Croix. The New Phytologist 1: 60–67. *pl. 1*. 1902.

[22] On the structure and affinities of Dipteris, with notes on the geological history of the Dipteridinae. Phil. Trans. Roy. Soc. London 194: 487-513. *pls. 47-49*. 1901.

[23] Note on the embryo of Nymphaea. Science 15: 316. 1902.

spherical mass of cells gives rise to two opposite and distinct cotyledons, with the plumule between them. Later the cotyledons become hemispherical and concave, applied against each other all round by the edges, and enclosing a central cavity occupied by the plumule. This seems to indicate that the embryo of Nelumbo must be regarded as dicotyledonous and unsymmetrical, rather than monocotyledonous with a two-lobed cotyledon.—J. M. C.

GEORGE H. SHULL[24] has made a quantitative study of variation in the bracts, rays, and disk florets of certain species of Aster. His conclusions are that there is a close correlation between bracts and rays, arising from the fact that the rays are axillary to the bracts; that the degree of imbrication of the bracts bears a relation to the number of empty bracts; that in a single group of specimens of *A. prenanthoides* the number of bracts, rays, and disk florets decreases continuously from the beginning to the end of the flowering season; and that the character of the curves and the position of their means and modes likewise change continuously. Curves and constants were determined for the material studied; and constants determined for several individuals of *A. punicus*, growing in identical surroundings, indicated how great variations may exist in the variability constants of individuals.—J. M. C.

IN HIS THIRD PAPER[25] on American ferns, Professor Underwood discusses the order of their relative importance, are (1) type of venation, (2) habit and growth characters of stem, (3) position of sori in relation to veins, and (4) indusial characters. His history of the migration and shifting of generic names and limits reveals a tangled mass of nomenclature, and proves the necessity of some agreement for anchoring generic names. The fifteen American genera of Aspidieae, only three of which are represented in the Northern States, are recognized as follows: *Leptogramma* J. Sm., *Phegopteris* Fée, *Plecosorus* Fée, *Polystichum* Roth., *Cyclopeltis* J. Sm., *Didymochlaena* Desv., *Camptodium* Fée, *Dryopteris* Adans., *Phanerophlebia* Presl, *Goniopteris* Presl, *Meniscium* Schreb., *Cyclosorus* Link, *Fadyenia* Hook. & Baur, *Tectaria* Cav., and *Sagenia* Presl.—J. M. C.

ANOTHER PAPER proving that the pollen mother cell of Asclepias gives rise to four microspores has just appeared.[26] Strasburger[27] and Frye,[28] whose

[24] A quantitative study of variation in the bracts, rays, and disk florets of *Aster Shortii*, *A. Novae-Angliae*, *A. puniceus*, and *A. prenanthoides*, from Yellow Springs, Ohio. Amer. Nat. **36**: 111–152. 1902.

[25] Bull. Tor. Bot. Club **29**: 121–136. 1902.

the genera of Aspidieae. The several characters he takes into account, in

[26] GAGER, C. S., The development of the pollinium and sperm cells in *Asclepias Cornuti*. Annals of Botany **16**: 123–148. *pl.* 7. 1902.

[27] STRASBURGER, E., Einige Bemerkungen zu Pollenbildung bei Asclepias. Ber. Deutsch. Bot. Gesells. **19**: 450–454. 1901.

[28] FRYE, T. C., Development of the pollen in some Asclepiadaceae. BOT. GAZ. **32**: 325–330. *pl.* 13. 1901.

work was done independently and whose results were published almost simultaneously about six months ago, made it plain that the mother cell gives rise to a row of four microspores. Both writers based their conclusions upon a cytological study of the mother cell, and the mitoses which occur as the mother cell gives rise to the four spores. Mr. Gager traverses about the same ground and arrives at the same conclusions. Four years ago W. C. Stevens[29] made the statement that "in *Asclepias Cornuti* the pollen mother cell divides twice, producing a radial row of four pollen grains." The statement is made as if the writer were referring to an accepted fact, and not as if he were making a contribution. Being referred to in this incidental way, in a paper devoted to a study of the kinoplasm and nucleolus, this unconscious contribution might possibly have been overlooked even if it had appeared in a journal of wide circulation; but appearing as it did in a university quarterly, it was as thoroughly buried as if it had been published in an agricultural bulletin. Real contributions to morphology or cytology are so infrequent in such publications that they are almost sure to be lost unless the investigator happens to recall them on account of personal copies among his separates. Any one of the four papers is sufficient to prove conclusively that in Asclepias the pollen mother cell gives rise to four pollen grains, instead of being transformed directly into a single pollen grain, as was formerly supposed.—CHARLES J. CHAMBERLAIN.

ITEMS OF TAXONOMIC INTEREST are as follows: B. L. ROBINSON (Rhodora 4: 65–73. *pl. 35.* 1902), in presenting the New England species of Polygonum of the section Avicularia, has described a new species (*P. Fowleri*).—ARTHUR BENNETT (Jour. Bot. 40: 145–149. 1902), in continuing his "Notes on Potamogeton," describes two new species (*P. rectifolius* and *P. strictifolius*) from the United States.—E. L. GREENE (Ottawa Nat. 16: 32–34. 1902) has published five new species of Ranunculus from various regions of the United States and Canada.—N. L. BRITTON (Torreya 29: 43. 1902) has described a new Peperomia from the Island of St. Kitts, British West Indies.—TAUBERT (Bull. Acad. Roy. Sci. Danemark. pp. 175–179. *pls. 3–4.* 1901) has described two new Brazilian genera (*Glaziocharis* and *Triscyphus*) of Burmanniaceae from the collections of Dr. A. Glaziou.—PH. VAN TIEGHEM (Jour. Botanique 15: 389–394. 1901) has described a new Brazilian genus (*Epiblepharis*) which belongs with Luxembourgia in the family (Luxembourgiaceae) he has set apart from Ochnaceae. He has also described (*idem* 16: 33–47. 1902) three additional new genera (*Setouratea, Campylospermum*, and *Bisetaria*) of Ochnaceae.—P. A. RYDBERG (Bull. Torr. Bot. Club 29: 145–160. 1902), in his seventh paper entitled "Studies on the Rocky mountain flora," describes new species

[29] STEVENS, W. C., The behavior of the kinoplasm and nucleolus in the division of the pollen mother cells of *Asclepias Cornuti*. Kansas Univ. Quarterly 7: 77–85. *pl. 15.* 1898.

of Aquilegia (4), Delphinium (5), Aconitum (4), Anemone (3), Clematis (2), Atragene (3), Ranunculus (4), Papaver, Argemone and Bicuculla.—G. E. OSTERHOUT (*idem* 173–174) has described a new species of Hesperaster from Colorado.—ELSIE M. KUPFER (*idem* 137–144. *pl. 8*), in studies of certain genera of Pezizineae, reestablishes Urnula, determines the relationship between Geopyxis and Urnula, and establishes the new genus *Chorioactis* (Pezizaceae). —J. M. C.

WILLIAM H. LANG[30] has been able to secure in Ceylon abundant prothallia of *Ophioglossum pendulum* and *Helminothostachys zeylanica* for study. The subterranean, tuberous, saprophytic character of the gametophyte of Ophioglossaceae is well known, and in the main these studies bear out those of Campbell and Jeffrey on Botrychium. In Ophioglossum the prothallium is usually branched, the short branches radiating in all directions; while in Helminthostachys there is a lobed basal portion from which arises a cylindrical process bearing the sex organs. In both an endophytic fungus is present. The antheridia and archegonia, so far as their development and structure were determined, present no new features. The author discusses the problematical relationships of the Ophioglossaceae, from the standpoint of the gametophyte, including its anatomy. He is inclined to believe that there are no constant characters of morphological value that indicate affinity between Ophioglossaceae and the Lycopodiales. On the other hand, the form of the prothallium, the structure of the sexual organs, and the embryogeny of the Ophioglossaceae are to the author such as might be expected in saprophytic forms derived from prothallia of the general type found among Filicales.

In this same connection reference should be made to the alga-like prothallium of *Schizaea bifida*, an Australian fern described by A. P. W. Thomas.[31] A similar prothallium has been described by Mrs. Britton and Miss Taylor for *S. pusilla*, as noted in this journal (31 : 363. 1901). The prostrate filaments give rise to erect ones that branch profusely, rising to a height of 3–4^{mm}. These prothallia differ from the well-known filamentous ones of Trichomanes in that they are completely filamentous throughout, the venter of the archegonium being entirely free, and even narrowed at the base, remarkably resembling the archegonia of bryophytes in this regard. —J. M. C.

THE QUESTION OF ABSORPTION AND EXCRETION of water and solutes by foliage leaves has been made the subject of a long and varied series of

[30] On the prothalli of *Ophioglossum pendulum* and *Helminthostachys zeylanica*. Annals of Botany **16**: 23–56. *pls. 1–3.* 1902.

[31] An alga-like fern prothallium. Annals of Botany **16**: 165–170. 1902.

experiments by Dandeno.[32] His most important conclusions are as follows:

1. Wilted leaves absorb water when their surface is wet with this substance.

2. Solutes are absorbed in the same way. Certain plants (*e.g.*, Thunbergia, Justicia) may be so arranged as to take up in this manner all the solutes necessary for growth. In the case of Justicia, plants whose leaves were supplied with solutes for seventeen days contained at the end of that time ash to the amount of 17.89 per cent. of their dry weight; similar plants not so supplied contained only 16.37 per cent. of ash.

3. Solutes diffuse outward from leaf tissues when the surface of the leaves is wet with water. These may be resorbed as stated under 2. Guttation drops (tomato, Impatiens, Phaseolus, etc.) and dew drops upon leaves contain salts, mainly $CaCO_3$. When evaporation is too rapid for complete resorption to take place, incrustation results. Distilled water left in contact with living leaves usually becomes alkaline.

4. Solutions applied to the cut end of the petiole of a detached leaf are absorbed and transmitted throughout the leaf. If they have a bad effect upon the leaf, this may be in one of two ways: (*a*) osmotically they may extract water from the leaf cells, thus causing plasmolysis and evident translucence of the affected parts through the presence of water in the intercellular spaces; (*b*) they may affect the cells in a chemical way, in which case no translucence is produced. Ascent in the veins takes place at a rate proportional to the length of the veins; the outline of the affected portion of the leaf is at any time similar to that of the whole leaf.

5. Cut twigs of Salix in early spring show more rapid and better development of the buds when supplied with distilled water than when supplied with a nutrient medium. It is immaterial where this water is absorbed, whether through young leaves, through the cut ends of the twig, or through roots which have grown out. Water cannot be absorbed through the bark.

The experiments are not well summarized, and theoretical suggestions are jumbled with demonstrated facts, so that the paper is difficult to read. The methods by which the experimentation was conducted are quite fully described, and for the points enumerated above they appear sufficient. But several other series of experiments are so unsatisfactory that it seems as though they might have been omitted with an increased clearness of the article as a whole. A rather copious literature is cited, but poorly cited, titles and references being incompletely given.—BURTON E. LIVINGSTON.

[32] DANDENO, J. B., An investigation into the effects of water and aqueous solutions of some of the common inorganic substances on foliage leaves. Transactions of the Canadian Institute 7: 238–350. 1901.

In his paper on causes governing the direction of branch growth Baranetsky[33] presents some new results of experimentation in this field. The author used entire plants, a number of woody and several herbaceous species being brought into requisition. The stems and branches were first bent into various positions and held thus until a geotropic growth curve had resulted, after which the plants were freed and placed upon a revolving klinostat. One of the most important results of the study of these rotating plants is the discovery of what is termed "opposite bending." By this the author means that phenomenon wherein the plant not only straightens a previously formed geotropic curve, but passes the original vertical position and bends in the opposite direction. After the first opposition curve is formed, a return to the original curvature may result, giving a pendulum-like motion of the tip, which exhibits several vibrations of gradually decreasing amplitude, until at length the normal position is reached. Such curving is ascribed to an accelerated growth on the concave side, of sufficient vigor to throw the tip beyond its first position. This then stimulates growth on the new concave side, but with lessened intensity, thus producing the vibration just noted. In his explanation of this opposition curve Baranetsky differs from Vöchting and Czapek, who hold that the increased growth on the concave side is merely sufficient to return the tip to its original position. Baranetsky also suggests that growth on the concave side may be aided by an inhibition on the convex side due to stretching of the cells.

Baranetsky carried on observations in the field as well as by laboratory experiments. The forms studied are divided according to their behavior into three types: the Prunus type includes Aesculus and Euonymus; the linden type includes Ulmus, Fagus, Crataegus, Celtis, and Corylus; and the needle-leaf type includes the pines. The first group is characterized by the upward turning of the side buds, the second by their downward turning, and the third by the wavy branches and sharply turned up tips. For the first type the author states the four following points: (1) physiological bilaterality is absent; (2) lateral shoots behave as main shoots; (3) all shoots are negatively geotropic; and (4) each curve produces an opposition curve which may either lessen or overcome the geotropic curvature. For the second and third types he finds (1) that weight plays an important part in directing the position of branches; (2) that geotropism is very powerful, often forcing the tips to a vertical position even in nature; (3) that epinasty is so slight that it cannot overcome or greatly lessen the geotropic curve.

In general, the author finds that the response to geotropism varies greatly in different species even within the same genus. Nowhere was it found that a weight stimulus caused growth.— P. G. Wrightson.

[33] Baranetsky, J., Ueber die Ursachen, welche die Richtung der Aeste der Baum- und Straucharten bedingen. Flora 89: 138–239. 1901.

Dr. H. J. Webber in an interesting paper[34] gives the results of his further studies of *Zamia*. The two Florida species, *Z. floridana* DC. and *Z. pumila* L., were formerly incorrectly referred to *Z. integrifolia* Jacq.

It is an interesting fact that development proceeds normally for several days after the strobili have been removed from the plants, so that even living spermatozoids may be secured from such material. The movements of the spermatozoids were studied in a sugar solution.

Although the germination of the microspores was not studied in detail, it is probable that there is an evanescent prothallial cell in addition to the persistent prothallial cell and antheridial cell (second prothallial cell of the author) which are conspicuous in the mature pollen grain. After the division of the antheridial cell to form the stalk and body cells, the persistent prothallial cell and the stalk cell become filled with starch and the former arches into the latter so that there is often the appearance of one cell entirely surrounding the other. The blepharoplasts first appear in the body cell (central cell) and are formed *de novo* from the cytoplasm. They are at first very small, being scarcely more than points where a few radiating filaments converge, but as they increase in size, a surrounding membrane and vacuolated contents can be seen. Shortly before the division of the body cell, the nucleus passes through a synapsis stage which is regarded as normal and not at all due to reagents. The spindle is developed while the nuclear membrane is still intact. It is apparently entirely of nuclear origin and none of the fibers have any connection with the blepharoplasts. During the equatorial plate stage, the blepharoplasts break up and in an early anaphase the contents have entirely disappeared, while the outer membrane soon breaks up into numerous granules, which during the formation of the cell plate begin to fuse, thus forming the cilia-bearing band. At first, the band is located in the cytoplasm midway between the nucleus and the periphery of the cell, but it ultimately moves out and becomes appressed to the plasma membrane, where it forms a helicoid spiral of from five to six turns. The entire spermatid is metamorphosed into a spermatozoid, there being no differentiation of a spermatozoid within a mother cell. The mature spermatozoids are the largest known in any plant or animal, being visible to the naked eye. They move mainly by means of cilia, but there is also an amoeboid movement of the spiral end.

In fertilization the entire spermatozoid enters the egg, but the nucleus soon slips out from the cytoplasmic sheath, leaving the ciliiferous band in the upper part of the egg. The nucleus moves on and fuses with the egg nucleus. There is a fusion of cytoplasm with cytoplasm and nucleus with nucleus.

[34] Webber, H. J.: Spermatogenesis and fecundation of Zamia. U. S. Dept. of Agriculture, Bureau of Plant Industry. Bull. no. 2. pp. 1–100. *pls. 1–7.* 1901.

Webber still believes that the blepharoplast is not the homologue of the centrosphere or centrosome because it differs from the centrosome "(1) in not forming the center of an aster at the pole of the spindle, being located entirely outside of the spindle in Zamia, Cycas, and Gingko; (2) in having no connection with spindle formation; (3) in being limited to the division of a single cell, thus to one cell generation, no similar organ appearing in any other stage of the plant's development, so far as known; and (4) in having a function differing from that of any typical centrosome, so far as known in plants."—CHARLES J. CHAMBERLAIN.

THE TRANSMUTATION THEORY of Darwin does not, according to Korschinsky,[35] explain how variations come about nor the origin of new forms. As a study of the wild forms alone could not solve the problem, he turned to the cultivated plants for a solution, and asserts for the latter that "no breeder has ever operated with individual variations for the production of new races, and that there has never been observed a heaping up of such variations. On the other hand, all new varieties (with the exception of crosses) whose origin is known developed as sudden variations of true species or hybrid forms." May not these sudden variations play the same rôle in nature, and may not this be an explanation of the discrepancies between the nature and occurrence of variations and the Darwinian theory?

The existence of sudden variations was well known to Darwin, but he laid little stress on these, holding them to be abnormal and exceptional. This sudden appearance Korschinsky calls "heterogenesis," and hopes to show that it is "though a rare yet completely normal phenomenon among plants and animals, and plays in their development an extraordinarily important rôle." The characteristics of heterogenesis is the topic of this paper, to be followed by another in which its rôle in the origin of species is to be treated.

The history of the term "heterogenesis" is traced to Kölliker and his explanation given, whereupon many cases of sudden variations are brought up and discussed. The sources are mainly French. He sums up to show that there appears suddenly a new race as fixed and as constant as those existing from immemorial time. Some persons have explained these as cases of atavism, others as monstrosities; but Korschinsky believes that "heterogenesis often makes it possible for atavism to show itself," and again that "the manifestation called heterogenesis shows itself in the unexpected appearance of different variations from the typical structure. Functional disarrangement of organs is an accompaniment of some, and these are monstrosities; other variations, however, do not disturb the vital functions of

[35] KORSCHINSKY, S., Heterogenesis und Evolution. Ein Beitrag zur Theorie der Entstehung der Arten. Translated from the Russian by S. Tschulok of Zürich. Flora 89: 240–363. 1901.

the organism and give rise to particular races." Considering all morphological peculiarities and physiological qualities as the results of heterogenesis, we must acknowledge that they do not differ in general from other types or races existing from time immemorial, and which latter, based on the Darwinian theory, we ascribe with confidence as having developed by means of a slow heaping up of characteristics and continuous selection. As, however, we know nothing of the way by which the forms of all wild and the greater proportion of cultivated plants have come about, there comes the question: Is the event of the development of new forms by way of heterogenesis so seldom and exceptional? Does it not occur oftener than we think, and does it not play a certain rôle in the evolution of forms in the plant kingdom? He takes up variability in garden plants under the most prominent forms, and discusses the many observations that have accumulated. Some of his main topics are variations of growth, variations of stem, of crowns, form of leaves, color of leaves, color of flowers, in structure of flowers, variations in blooming, and in fruits. On the basis of this study the peculiarities of heterogenetic characteristics are to be found in the more or less prominent variations readily distinguished from the combinations of unimportant variations which make up an individual in a group of its kind; that is, in the absence of hybridity or heterogenesis, there will be no characteristics radically distinguishing one individual from another.

The direction of variability and the characteristics of heterogenetic variation bring out an interesting discussion of sports. It is characteristic of heterogenetic variations that they are constant, not only by vegetative reproduction, but also when propagated from seed, although, especially in the first generations, some aberrant forms may appear.

Inheritance and variability, whatever their real causes, may be thought of as two forces hidden in the organism, as two antagonistic tendencies. Under normal conditions, we have the identity of succeeding generations, but the tendency to vary is not constant. "It (the tendency to vary) must, so to say, gather the necessary energy during many generations in order finally to overcome the power of inheritance and to give rise to a heterogenetic race." The mechanism resulting in this appearance must be sought in the changes taking place in the sexual products, that is, either in the pollen or in the ovule. It seems probable that the variations are initiated during or after fertilization. The cause of this change, and why one ovule and not another is influenced, remains completely inexplicable.

The list of references at the close covers five and one-half pages.—G. N. Lauman.

NEWS.

A CHAIR OF BACTERIOLOGY in the University of Edinburgh has been endowed by the will of Mr. Robert Irvine.

PROFESSOR FLAHAULT, the well known botanist at Montpellier, has been chosen Chevalier of the Légion d'Honneur.

DR. JOHANNES CHRISTOPH KLINGE, of the botanical gardens at St. Petersburg, recently died at the age of fifty-one.

DR. C. S. BELLI, formerly of Turin, has been appointed professor of botany and director of the botanical gardens at Cagliari.

DR. F. CAVARA, formerly of Cagliari, has been appointed professor of botany and director ot the botanical gardens at Catania.

A VERY INTERESTING ACCOUNT of the palm trees of Brazil has been published in *Popular Science Monthly* for March by Professor John C. Branner of Stanford University.

DR. B. E. FERNOW, director of the New York State College of Forestry, will deliver a course of lectures on forestry at the University of California in the coming summer session.

PROFESSOR G. POIRAULT, director of the laboratory at Villa Thuret, has been elected professor at l'École Nationale d'Horticulture de Versailles in place of Professor Cornu, deceased.

THE DANISH GOVERNMENT, which has done so much for the exploration of western Greenland, has sent a party to the east coast for the purpose of botanical exploration. Dr. Kruuse is the director of the expedition.

THE SEVENTY-SECOND ANNUAL MEETING of the British Association for the Advancement of Science will be held at Belfast, beginning September 10. The president of the botanical section is Professor J. Reynolds Green.

THE ADDRESS of Dr. Erwin F. Smith as president of the New York meeting of the Society of Plant Morphology and Physiology, on "Plant pathology: a retrospect and prospect," is published in *Science* for April 18.

ATTENTION is called to the rules for citation printed on the page following the table of contents. It is to be hoped that every contributor, at least of leading articles, will be guided by them in his preparation of manuscript.

THE STOKES PRIZE for the best essay on the preservation of our native flora has been awarded for the current year to Dr. F. H. Knowlton. The

essay is printed in the March number of the Journal of the New York Botanical Garden.

Professor E. Zacharias, formerly director of the botanic gardens in Hamburg, has been appointed director of the Government Botanical Institute of Hamburg, comprising botanical garden, museum, and laboratory for economic work.

Professor B. D. Halsted has been compelled to give up his work for a time on account of illness, and as a consequence will not be able to give the presidential address at the meeting of the Botanical Society of America at Pittsburg.

Associate Professor Cummings has been placed in charge of the department of botany at Wellesley College since the retirement of Professor Hallowell from active service, and all correspondence intended for the department should be addressed to the former.

Professor A. N. Berlese, professor of botany in the University of Sassari, has been appointed professor of vegetable pathology in the school of Agriculture at Milan. He is succeeded by Professor G. B. DeToni, now of the University of Camerino.

Gebrüder Borntraeger announce a second edition of Warming's *Lehrbuch der ökologischen Pflanzengeographie*, revised and brought up to date by Dr. Paul Graebner, whose previous ecological studies amply equip him for a work of this importance.

The eleventh session of the Hopkins Seaside Laboratory, in connection with Stanford University, will begin June 9. The following courses in botany will be given by Dr. A. A. Lawson: Elementary botany, Introduction to the study of seaweeds, Plant cytology and microtechnique.

The Harvard Station in Cuba, at Colonia Limones, about twenty miles from Cienfuegos, is testing the possibility of repeating in the climate of Cuba the well-known Javan studies in the pollination of sugar-cane. The work is in charge of Robert M. Grey, an experienced hybridizer.

Dr. D. T. MacDougal, of the New York Botanical Garden, has returned from his trip to Arizona and Sonora with an extensive collection of giant cacti and other xerophytes for the garden. Dr. N. L. Britton, Director of the garden, has gone on a collecting trip to Cuba; and Professor F. S. Earle is also collecting for the garden in New Mexico and Texas.

In the summer of 1902 two ecological expeditions will be sent out from the University of Chicago. Dr. H. C. Cowles will conduct a party to Mt. Katahdin and the coast of Maine at the close of the session of the Woods Hole Marine Biological Laboratory. Mr. Harry N. Whitford will conduct a party to Flathead Lake and the Montana Rocky mountains during the month of August.

A PRICE LIST of botanical laboratory supplies, recently published by the Marine Biological Laboratory, may be obtained from Mr. George M. Gray, Woods Hole, Mass. Special emphasis is given to marine algae, which are sold in sets mounted on cards for demonstration purposes, and also as preserved material for the laboratory. Types of fresh water algae, fungi, mosses, and liverworts are also offered.

A LIST of economic and other fungi prepared for distribution by the Division of Vegetable Pathology and Physiology has been published, prepared by Flora A. Patterson. Each state agricultural experiment station is invited to select fifty specimens from the list, and all over fifty may be considered as in exchange. The benefits of this exchange are extended also to all who are interested in the study of fungi from the economic standpoint.

IN THE LATTER PART of March Professor C. B. Davenport and Dr. H. C. Cowles of the University of Chicago conducted a party of students to the gulf coast of Mississippi. The party was joined by Professor S. M. Coulter of Washington University, Dr. W. S. Leathers of the University of Mississippi, and Mr. S. M. Tracy of Biloxi, Mississippi. Valuable collections were made of plant and animal material, and a considerable number of representative photographs were obtained.

IN *Ber. Deut. Bot. Gesells.* for March 10 biographical notices of six deceased members of the society appear. The notice of ALBERT BERNHARD FRANK, who died September 27, 1900, at the age of 61, is prepared by Friedrich Krüger; that of ROBERT HEGLER, who died September 29, 1900, at the age of 33, by G. Karsten; that of KARL DUFFT, who died October 11, 1900, at the age of 75, by Carl Holtermann; that of SSERGEI IWANOWITSCH KORSHINSKY, who died December 18, 1900, at the age of 39, by G. Tanfiljew; that of MAXIME CORNU, who died April 3, 1901, at the age of 57, by P. Magnus; and that of A. F. WILHELM SCHIMPER, who died September 9, 1901, at the age of 45, by H. Schenck. The last notice is accompanied by a portrait.

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PHYSIOLOGICAL OBSERVATIONS ON THE SUBTERRANEAN ORGANS OF SOME CALIFORNIAN LILIACEAE.

A. RIMBACH.

(WITH PLATE XIV)

DURING my stay in the neighborhood of the Bay of San Francisco I have endeavored to get acquainted with the life-history of some of the numerous species of Liliaceae growing wild in that region, and my attention has been drawn especially to the physiological behavior of their subterranean organs. As the plants concerned exhibit some quite remarkable features, and have been little studied in this respect, and as they include some species of rather limited geographical distribution, I will give in the following pages an account of my investigations.

CLINTONIA ANDREWSIANA Torr.

The seeds of *Clintonia Andrewsiana* germinate in March. The cotyledon, after having absorbed the contents of the endosperm, serves as the first green leaf, growing 10^{cm} long and 3^{mm} wide. The primary root, 1^{mm} thick, reaches over 10^{cm} in length, and forms a few branches of the 1st degree. Its central cylinder is 3-archic, the endodermis with slightly thickened walls, the cortex starch-bearing. There are no signs of contraction. The stem develops into a rhizome, which grows almost vertically downwards to a depth of about 8^{cm}, where it passes over into the horizontal direction. Its annual prolongation is in young

specimens 1 to 3 ^{mm}, in adult ones 5 to 15 ^{mm}. Every year's formation may live over 20 years, so that the rhizome may attain a length of 15 ^{cm} and more. At first it forms yearly but one leaf; afterwards a stem 5 ^{cm} high with two leaves; finally a stem 12 ^{cm} high, crowned with about six leaves, and prolonged into the inflorescence. The leaves last very long, appearing above the ground in February and remaining green until October or November. The youngest portion of the rhizome develops every year, from October until April, the new roots being one or two in young, four to six in full-grown specimens. Their direction is downwards or sidewards. They are uniform throughout, without contraction, branch sparingly in the 1st degree, and are covered with root hairs. In adult specimens they are 2 ^{mm} thick, over 20 ^{cm} in length, and last about fifteen years. The central cylinder is 12-archic, its innermost part made up of thick-walled cells. The endodermis exhibits strong V-thickenings and thin-walled passage-cells in front of the hadrome rays, and there are no foldings on its longitudinal walls. The moderately abundant cortex is starch-bearing.

In Clintonia the roots are storing organs, but the rhizome is also rather rich in starch-bearing parenchyma. The roots have no influence upon the position of the rhizome. This latter grows downwards or upwards according to circumstances, and is sometimes very much curved.

PROSARTES HOOKERI TORR.

I found the seedlings of *Prosartes Hookeri* in the middle of April in an advanced state, yet still in connection with the seed. The germination probably takes place in March. The cotyledon, about 10 ^{mm} long, remains underground with its tip within the seed. The primary root, 0.75 to 1 ^{mm} thick, reaches over 10 ^{cm} in length, is uniform throughout, and branches in the first year sparingly in the 1st degree. It is provided with long root hairs. Its central cylinder is 9-archic, and the endodermis has slightly thickened walls. The cortical parenchyma is abundant and full of starch, and there is no contraction.

Immediately after germination the first aerial stem appears,

5–12^{cm} high, bearing two foliage leaves. There takes place the formation of a rhizome, which grows downwards, and elongates every year, at first 1 to 2^{mm}, later 3–5^{mm}, in adult specimens 5 to 15^{mm}. In old individuals it acquires a considerable length, comprising the formations of many years.

The head of the full grown rhizome produces yearly about five roots. These are 1 to 2^{mm} thick, over 20^{cm} long, uniform in all their length, or even increasing a little in diameter at some distance from the base. They run downwards and sidewards, wind very much from the start, and branch sparingly in the 1st degree. Their central cylinder is usually 18-archic, and made up in its innermost part of strongly thickened, very narrow cells. The endodermis has very strong, yellowish V-thickenings, and the adjacent two or three layers of the cortex are also somewhat thick-walled. The cortical parenchyma is abundant and contains starch. The epidermis forms long root hairs. Endodermis and hypodermis do not show any folding of their membranes. There is not the slightest indication of shortening of the root.

The rhizome of Prosartes is often very crooked. It may grow vertically upwards or downwards, according to circumstances. The roots have no influence upon its location.

Prosartes Menziesii Don. behaves just like *P. Hookeri*.

FRITILLARIA LANCEOLATA Pursh.

The peculiarly shaped rhizome of *Fritillaria lanceolata* does not penetrate to a great depth. Its direction of growth is in young specimens sometimes inclined, in full-grown ones, situated 4 to 6^{cm} below the ground, horizontal. The yearly advance of the rhizome in horizontal direction amounts to 5 or 8^{mm}. Every new formation lasts but one year. There is a profuse vegetative multiplication, as larger specimens produce from 30 to 60 lateral bulblets. The plant brings forth yearly in younger specimens three or four, in adult ones about twenty thread-like roots, 0.5 to 1^{mm} thick and almost 10^{cm} long, branching in the 1st degree. The roots originate all at once, from one point, and run immediately in a horizontal direction. They have a

3-archic central cylinder and a thin-walled endodermis; both endodermis and hypodermis are without foldings. The roots are purely nutritive.

LILIUM PARDALINUM Kellogg.

In the gulches round Mount Tamalpais, where *Lilium pardalinum* grows in moist, shady places, I found the seedlings in an advanced state, but still connected with the seed, in the middle of April. The cotyledon, 5^{mm} long, remains underground, and its tip does not abandon the seed. Immediately after germination, however, a foliage leaf 4^{cm} high is formed. The primary root is 0.5^{mm} in diameter, furnished with hairs. Its central cylinder is 2-archic, the endodermis cells slightly thickened. The cortex is thin, and no signs of contraction are present.

The shoot develops into a bulb, the axis of which takes up a horizontal direction. The young plant produces every year but one foliage leaf and one to four fleshy scales; also the fleshy base of the foliage leaf, after withering of the blade, remains alive, functioning like a bulb-scale. In such specimens the bulb axis is about 3^{mm} long, and comprises but one year's product. It produces in the first periods two to four, later four to eight roots, originating exclusively from the lower side. Most of these roots are swollen at the base to 2^{mm} diameter, and shorten in this portion, so as to become wrinkled on the surface to an extent of 10 or 15^{mm}. As these contractile roots start from one point and grow almost vertically downwards, spreading away only by their ends, and as the bulb in the young individuals is very narrow, the latter is buried easily in the earth. Hence we find, while the seedlings are scarcely 1^{cm} below the ground, that half-grown specimens are 5 or 6^{cm}, full-grown ones 8 to 11^{cm} in depth.

At the time when the first aerial stem is brought forth the bulb axis is about 5^{mm} long, and produces about ten scales yearly. For full-grown individuals the annual prolongation amounts to 1 to 3^{cm}, and as a rule is horizontally directed. In this latter stage of development every year's formation lasts five

to seven years, and thus an old rhizome acquires a length of about 12^{cm}. Upon its upper side the rhizome bears the scars of the vanished aerial stems, each surrounded by a large number of bulb scales; at its basal end it is separated by a smooth scar from the dead portion. On its lower side the roots are found, five to twelve to each year's formation, starting rather close to each other. They are over 15^{cm} long, in their basal portion swollen to 3^{mm} in diameter, and branch rarely in the 1st, very rarely in the 2d degree. They live about five years, and grow from the beginning almost vertically downwards, but soon change their course into the horizontal direction. The swollen part is contractile, and becomes wrinkled to a length of from 5 to 20^{mm}. The central cylinder is 10-archic, the endodermis furnished with yellowish 0-thickenings. In the active cortical parenchyma the cells of the innermost layers are radially elongated, those of the outer strata collapsed and compressed. Both endodermis and hypodermis show the radial longitudinal walls undulated. The epidermis bears root hairs.

In the thin, non-contractile end-portion, which otherwise has the same structure, the undulation of endodermis and hypodermis, the radial elongation of the cortex-cells, and the compressed cell-layers are wanting.

In the adult specimens, which have an ample growth of the horizontal rhizome and branch quite often, the roots apparently have no longer any considerable influence upon the position of the plant. I never found the position of the older parts disturbed. Specimens buried to an excessive depth are found sometimes growing up vertically and forming quite thin, smooth roots.

SCOLIOPUS BIGELOVII Torr.

Scoliopus Bigelovii grows in the shade of the redwoods, in moist, cool places. As is known, it flowers early in the year; in 1901 I found the last flowers at Mount Tamalpais at the end of February. By the prolongation and curvature of the stalks the ripening fruits are brought close to the soil, and there they open. I saw the first open fruits at the end of April. In many

instances I found seedlings and young individuals of different ages in dense patches at a distance of at most 30^{cm} from isolated mother plants. Owing to the length of the stalk the fruit can reach at most the distance of 15^{cm} from the center of the plant. There does not seem to exist any arrangement for the spreading of the seeds.

The seeds were found germinating in February. The cotyledon remains with its tips for some time in the seed, while its middle portion breaks above the ground by a knee-like curvature (*fig. 1*). Then it leaves the seed and stretches out, being the first green leaf of the plant. The primary root, 1^{mm} thick and beset with long hairs, reaches only 3^{cm} in length and does not branch. It has the central cylinder 2-archic, and a thick cortex. The latter becomes filled with starch-grains, except in the basal portion, where starch is almost absent; but here the undulation of the endodermis points to a slight contraction. After germination the diminutive stem of the seedling is at most 2^{cm} below the ground.

While the cotyledon dies down in the first summer, primary root and stem persist several years, the latter developing into a rhizome, the annual growth of which amounts at first to about 1^{mm} only. I do not know what the tendency of the rhizome may be regarding its direction of growth. The fact is, that the rhizome, in young specimens of normal, superficial location, assumes an almost vertically downward direction, with the growing point at the lower end (*fig. 2*). But this position, to a great degree if not exclusively, is due to the action of the roots. For the later roots, sometimes even the second one, shorten considerably, and as they all point more or less steeply downwards, they exert a pull upon the rhizome and drag it gradually deeper into the soil. However, as each root contracts only during the first months of its development, the older roots are out of action, and the pull is brought about only by the youngest ones, which arise from the growing end of the rhizome. This circumstance explains also the phenomenon that, while the youngest roots are quite straight, the inactive ones are (the older the more) curved

and bent down in their basal portions, apparently dragged by the movement of the rhizome to which they are attached (*fig. 2*).

The rhizome of old specimens is 3 to 5 cm long, comprising the products of twenty to thirty years, and is found at a depth of 5 to 7 cm. Here it has a horizontal direction, with an annual prolongation of 1 to 3 mm. It branches but rarely.

Young plants, which develop yearly only one leaf, form only one or two roots, while full grown specimens, as a rule, form three each year. The roots break forth all at once, in January or February. They may live twenty years, and therefore there are found sometimes forty to fifty of them on one plant. In older specimens the roots reach 20 cm in length, branch in their end-portion rarely in the 1st degree, and bear numerous root hairs. They are between 2 and 3 mm thick, their basal part, when quite young, being somewhat swollen to 3 or 4 mm. Central cylinder and cortex retain the same proportion throughout the root. The cylinder is mostly 8-archic, the rays being reduced somewhat in number towards the tips. The branches are 4-archic. The endodermis is made up of narrow cells with O-thickenings and thin-walled passage-cells in front of the hadrome-rays. The cortical parenchyma is abundant and the hypodermis very distinct.

This being the general structure of the fully developed root, there are to be noted some differences between the basal portion and the more terminal one, which are related to the functions of these parts.

As already stated, each section of the basal region, soon after having finished its growth in length, begins to shorten. During this process, the active cells of the cortical parenchyma change their form, growing not only shorter, but also broader and becoming radially elongated. In this contraction and change of form, the epidermis, hypodermis, and two layers of cells bordering upon the latter — a complex, which we may designate as *passive outer cortex* — do not join. The outermost layers of the active cortex after a time collapse, are compressed by the expanding inner ones, and form a gradually broadening

zone immediately inside of the passive outer cortex. None of these changes appear in the terminal portion of the root.

Besides, there exists another difference, noticeable even in the primary root, but more pronounced in older plants. In that portion where the cells do not undergo any considerable change of form and size, the cortical parenchyma is densely filled with starch grains; but in the basal region, as far as the parenchyma exhibits strong activity of contraction, starch grains are entirely absent.

The contraction of the cortical parenchyma causes changes also in the passive tissues, inside as well as outside of it. Inside it leaves very characteristic traces in the endodermis. This tissue behaves like the elements of the central cylinder, becoming passively contracted in longitudinal direction. In the beginning, the cell-walls of the endodermis are straight and show nothing exceptional in their outer form, and so they remain in the end-portion of the root and in the branches throughout life. But in the basal portion, as far as contraction occurs, the radial-longitudinal walls of the endodermis become marked by an undulation running longitudinally. This undulation, here as in other species, corresponds to the dark spot, which is observed on the same wall on the cross-section. The undulation or wavy folding of the membrane is most pronounced near the root-base, where the strongest shortening takes place, and diminishes toward the root-end, being entirely absent near the tip.

Quite a similar phenomenon is to be noticed, outside of the active cortex, in the hypodermis. Also in this tissue, the membranes of which are quite straight at the beginning, as far as contraction reaches, an undulation of the radial-longitudinal cell-walls makes its appearance, becoming strongest in the basal region and diminishing and disappearing in the end-portion. The undulation of the cell-wall in both endodermis and hypodermis becomes fixed and remains nearly unaltered by separating these tissues in old roots from the adhering active parenchyma.

Some time after the appearance of the undulation, the pass-

ive outer cortex in its totality, in consequence of the shortening, loses its light connection with the active tissue beneath, becoming separated from it by the formation of the zone of compressed cells already mentioned. Hereupon the root-surface, tight and smooth at the beginning, becomes slack, rough, and wrinkled, and the whole root diminishes somewhat in thickness. The wrinkles begin to show themselves in March, when the roots are 6 to 10^{cm} long, still growing and without ramification. This wrinkled region, very insignificant in the first roots of the young plant, acquires in older specimens a length of about 2^{cm}.

Trillium ovatum Pursh.

Trillium ovatum lives in the same localities as Scoliopus, and also in its manner of life resembles this species in many respects. A difference of organization between both, noticeable even in the seedling, is that in Trillium the rhizome is used in a higher and the roots in a less degree as storing-organs than in Scoliopus.

I saw the germination already finished at the beginning of April. Seedlings and young plants of different age were found very often in the immediate neighborhood of the mother plant. While the cotyledon functions as the first foliage leaf, the stem of the seedling swells up to form a small tuber full of starch. The primary root, nearly 1^{mm} thick, reaching about 8^{cm} in length and forming a very few branches, contains but a small amount of starch grains, its central cylinder is 3-archic, the endodermis furnished with slight thickenings, remaining there as thin-walled passage-cells in front of the hadrome, the cortical parenchyma abundant, the hypodermis very distinct. There are signs of a feeble contraction in the root-base. Primary stem and root persist several years.

The second root, which in the following year breaks from the upper part of the tuber and grows vertically downwards, is considerably larger than the first one, has a thickened basal region, and exhibits there strong contraction, becoming finally wrinkled on the surface to an extent of 10 or 15^{mm}. In consequence of its

shortening it pulls down the tuber into a horizontal position, carrying with it also the basal part of the primary root.

The annual prolongation of the tuber amounts only to 1^{mm}, even in old specimens, but every year's addition broadens it, until in old tubers it comes to a permanent diameter of 10 to 15^{mm}. Such tubers are 3 to 4^{cm} long, containing the living products of twenty to forty years, and die off by degrees at the basal-end with a smooth scar. They do not branch. The full grown tuber brings forth on its lower side yearly two to four roots, situated close together and directed vertically downwards. The roots are about 30^{cm} long and 3 to 4^{mm} thick at the base, taper toward the tip, and branch there very sparingly in the 1st degree. They last about ten years, and twenty or more of them may be found attached to one tuber.

The central cylinder is 6-archic, the narrow-celled endodermis furnished with slight O-thickenings. The rather abundant cortex is almost devoid of starch grains in the swollen basal portion, but contains rather abundant starch in the thin terminal portion. The latter part of the root does not show anything extraordinary. The basal region, on the contrary, shortens very much, the active cortex cells elongating radially. As a result of the contraction, the radial-longitudinal walls of the endodermis become strongly undulated, a zone of compressed cells is formed below the outer cortex, and the root surface becomes wrinkled for a length of 3 to 5^{cm}.

The total shortening of the root probably amounts to about 10^{mm}. The main contraction goes on during the first months of the life of each root. Hence in Trillium, like in Scoliopus, mainly the youngest roots, situated nearest the growing end of the tuber, exsert a pull upon the latter. This pull brings it into an oblique, often vertical position, with the growing point at the lower end, so that the leaf stalk or the aerial stem forms a sharp angle with the rhizome. In this respect young specimens of Trillium and Scoliopus exhibit quite a similar appearance.

By degrees the roots drag down the tuber from the surface into the earth, so that old tubers are usually found 8 to 10^{cm}

below the surface. These latter, as a rule, are no longer inclined, but horizontal. I found here and there, however, always at a considerable depth, old tubers growing vertically upwards, with the roots starting equally from all sides. I am not quite sure about the conditions which provoke this kind of growth, nor about the tendency in the direction of growth the tuber may have in the other cases.

Zygadenus Fremonti Torr.

Zygadenus Fremonti inhabits sunny, dry localities among shrubs, being very frequent in the chaparral. I found the young seedlings in great numbers in January (*fig. 3*). The cotyledon is subterranean; its tip, which is a well separated, roller-shaped sucker 3 to 4^{mm} long, remains within the seed; its lower part elongates downwards, burying the small stem 5 or 10^{mm} into the ground. A linear, upright foliage leaf, 5 to 10^{cm} long, is at once developed. The primary root grows about 6^{cm} long, and is remarkable for its swollen basal part, which is about 1.5^{mm} in diameter. Its central cylinder is 4-archic, the cortex extremely thick. The swollen part contracts a good deal, and thereby buries the stem still more into the earth. At the end of the shortening, we find the endodermis undulated, the active cortical cells radially expanded, a narrow ring of compressed cells formed in their circumference, and the passive outer cortex wrinkled to a length of 15^{mm}. The primary root branches but sparingly in the 1st degree, and is the only one formed in the first year. It dies off in the early part of May.

The shoot of the plant develops into a bulb and produces every year in younger specimens two to four, in the adult ones 10 to 15 roots. The roots originate at the beginning of the rainy season, in December or January, and die off at the beginning of the dry season; hence from June to November the bulb is rootless. They are all contractile, although in a different degree, and send out from the terminal region branches of the 1st and 2d order. In young specimens they always originate from one side of the bulb, so as to bring, by their

one-sided pull, the bulb-axis into an oblique position. In half grown specimens the roots acquire their greatest diameter, about 6^{mm}, and probably also the greatest amount of shortening, and drag the bulb every year 1 to 2^{cm} downwards (*fig. 4*). Their course is very characteristic, the contractile basal portion pointing almost vertically downwards, the inactive terminal portion passing into the horizontal direction. The central cylinder in these roots is usually 8-archic. In full-grown, old specimens, the growing point of which, as a result of the dragging of the roots, lies at a depth of 10 to 12^{cm}, the roots are thinner, at most 3^{mm} in diameter, start equally from all sides of the bulb-axis, and run in a flatter course (*fig. 5*). Their central cylinder has on an average nine rays, that of the branches three rays. In April, when the contraction is ended, the endodermis is furnished with exceedingly strong O-thickenings of yellow color, the hollow of the cells sometimes almost being filled up; but thin-walled passage-cells are present in front of the hadrome-rays. The cortex is copious. Root hairs are numerous. The bulb keeps, as a rule, a vertical position, elongates from 3 to 5^{mm} every year, and comprises the products of two years.

Remarkable are the differences between the contractile basal portion and non-contractile terminal portion of the root. For instance, the central cylinder preserves its diameter throughout its whole length, only the number of rays diminishing very little toward the tip; the cortex, on the contrary, is twice as thick in the basal region as in the terminal. Furthermore, the radial-longitudinal walls of the endodermis acquire, in consequence of the shortening, a strong undulation in the basal part of the root (*fig. 6*), whereas in the terminal part they do not show this peculiarity (*fig. 7*). Finally, the endodermis remains in the basal region thin-walled, until the contraction is finished, while in the non-contractile terminal region the thickenings make their appearance before that time.

CHLOROGALUM POMERIDIANUM Kunth.

Chlorogalum pomeridianum grows in dry, open localities, preferring rocky hills. In its manner of life it shows much resem-

blance to Zygadenus. Like the aerial organs, the roots also last only one vegetative period, sprouting at the beginning of the rains, in December and January, and dying off at the beginning of dryness in June or July.

Young seedlings were found in the latter part of January (*fig. 8*). The cotyledon is subterranean; its upper end, a globoid sucker, about 4^{mm} wide, remains in the seed, the rest elongates about 10^{mm} downwards, carrying the stem as far into ground. At the same time the first foliage leaf is sent forth, about 7^{cm} long with a blade 4^{mm} wide. The primary root, 1^{mm} thick and 5^{cm} long, develops near its end a few branches. Its central cylinder is 3-archic, the cortex moderately abundant. Its basal portion shortens, and in the thin walls of endodermis and hypodermis appears a heavy undulation. Besides the primary root, during the first year one or more roots appear, longer and gradually thicker, but in form and function equal to the first one.

From the second year onward a difference shows itself in the formation of these organs. At first from two to eight thin, thread-like, non-contractile roots are formed. They arc 0.5 to 1^{mm} thick, have a 4- or 5-archic central cylinder, and a moderately abundant cortex. After these, one or more roots appear, similar to those of the seedling, very thick in the basal region and tapering towards the tip, strongly contractile and growing vertically downwards (*fig. 9*). The largest of these I found were 10^{mm} in diameter, and were thicker than the bulb from which they arose. In these the central cylinder is 9–12-archic, the endodermis thin-walled, the cortex enormously abundant. The latter shows the radial elongation of the cells and a wide zone of compressed tissue (*fig. 11*). Both kinds of roots branch for a time in the 1st and 2d degree.

The work of thc contractile roots is considerable. The downward movement of the bulb was in several specimens 1.5^{cm} during one vegetative period. In this movement the bulb carries with itself the thread-like roots of the present year and also the dead but still adhering roots of the preceding year (*fig. 9*).

Thus, the growing point of the bulb, lying in the seedling 1 or 2 ^{cm} below the surface of the earth, is brought finally to the depth of 10 to 15 ^{cm}. There it is met, as a rule, in the full grown specimens, in which the bulb has attained a large size (*fig. 10*). An adult specimen produces about seven roots each year. Among these the difference in form and function disappears; they are all of the same kind, about 5 ^{mm} thick, tapering soon to 3 or 2 ^{mm} in diameter, and take up not a vertical, but more oblique course from the start. They are very long, covered with hairs, and form later on branches of the 1st and 2d degree. Their central cylinder is usually 13-archic, but the cortex reduced in abundance compared with that of the napiform roots of the half-grown specimens. The annual prolongation of the bulb-axis amounts in these old plants to 5 to 8 ^{mm}. So much are they carried down by the roots, however, that a full grown bulb, very superficially located, moved down in one year 2.5 ^{cm}.

In connection with the study of Chloragalum I should like to emphasize some facts concerning the behavior of the contractile roots. In Chloragalum, as in other species, the contraction does not appear in the whole root at once. On the contrary, as each section of the root a short time after having finished its growth in length begins to shorten, necessarily the older basal sections commence their contraction earlier than the younger, more terminal ones; also the phenomena accompanying the contraction appear sooner in the base. Thus we see in the napiform roots of Chloragalum that after a time the bark, smooth and light at first, becomes slack and wrinkled at the base, diminishing also in diameter, and that by degrees this wrinkling and falling down advances toward the tip over all the swollen basal region (*fig. 9*).

The roots of Chloragalum do not wait to commence their contraction until they have attained their entire length, nor do those of Zygadenus, Trillium, Lilium, Scoliopus, Arisaema, nor any other species I know of. On the contrary, in all these the contraction sets in when the roots are quite short, a few centimeters in length.

Neither do the roots of our plant wait to contract until they

have anchored themselves by lateral rootlets. On the contrary, when the few branches are formed, the contraction of the root is nearly or entirely finished. The same is true for the described species of Zygadenus, Trillium, Scoliopus, and likewise for *Calochortus umbellatus*, *Brodiaea capitata*, *Arisaema Dracontium*, and others. There are even contractile roots of a very strong dragging effect, which do not branch at all, as is the case in *Arum maculatum* and *Fritillaria Meleagris*. Apparently the close adherence of the root surface with the earth gives a sufficient support, and it seems even that in certain cases the presence of root hairs is not necessary for bringing about the effect.[1]

CALOCHORTUS UMBELLATUS Wood.

The bulb of *Calochortus umbellatus* is brought from the surface of the earth, where the seed germinates, to a considerable depth exclusively by the action of contractile roots. The bulb axis always grows vertically upwards, but not more than 1 or 2 ^{mm} a year, even in full grown specimens, in which the bulb is about 2 ^{cm} high and 1 ^{cm} thick. The whole plant renews itself annually, every part of it lasting but one cycle of vegetation.

At the beginning of the rainy season the bulb produces ten to twenty thread-like roots, 0.5 to 1 ^{mm} thick and 10 ^{cm} long, which give off numerous branches of the 1st and 2d degree. Those roots have the central cylinder 3-archic, a thin-walled endodermis, a moderately abundant cortex, endodermis and hypodermis straight-walled; they do not contract and are merely nutritive (*fig. 13 r*).

After these there appears one large napiform, contractile root (*fig. 13* r^1.) It is in the basal portion from 2 to 4 ^{mm} thick, but is attenuated near the end to 0.5 ^{mm}. The central cylinder is 15-archic, and the cortical parenchyma copious. The active cortex cells elongate radially, their outermost layers collapse, and form a ring of compressed tissue bordering upon the passive outer cortex. The radial-longitudinal membranes of the thin-

[1] In regard to these details the descriptions of the phenomena concerned, as given in Kerner's *Plant Life* 2:769. 1891, and in MacMillan's *Minnesota Plant Life*, pp. 218, 219, 1899, are not exact.

walled endodermis become strongly undulated. After conclusion of the shortening, in April, this root ramifies sparingly. In larger specimens the root drags down the bulb 10 to 15 ^{mm}. By this movement the thread-like roots become displaced very much, and the bulb itself pulled out of the old husk, which sticks to the earth and remains in its place. The husks of several years sometimes persist, indicating the amount of work done by the roots in the respective periods (*fig. 13, h*).

Arriving at a depth of 6 or 7 ^{cm}, the plant stops the formation of contractile roots, producing then exclusively thread-like ones. In this state the new-formed bulb remains within the old husk, and at its bottom the remnants of the bygone bulb-axis accumulate, piled upón each other.

BRODIAEA CAPITATA Benth.

In full grown specimens of *Brodiaea capitata,* a species growing on sunny meadows, the subterranean part of the shoot is a tuber of vertical growth, rich in starch, about 15 ^{mm} thick, roundish, bearing on its lower end a round scar, the place where it was united with its predecessor. Its position is very superficial, only 3 to 5 ^{cm} below the ground.

It lasts but one year. In January, after starting the leaves, it begins to shrink and to become empty, but forms on its upper end a superposed new tuber. At the same time, from the base of the latter two pairs of lateral buds grow out, which likewise develop into small tubers, being supported by thin stalks about 1 ^{cm} in length (*fig. 14*). Each of these four lateral tubers is ensheathed by a fleshy sheathing scale, which later on dries up and becomes a brown husk. The stalks also die down, so that at the end of the rainy season the four small tubers are free, although still quite close to the mother plant.

The following year, at the beginning of the rains, mother and daughter tubers develop leaves and roots (*fig. 15*). The main tuber puts forth thirty to forty thin roots in a nearly horizontal direction, which become 10 ^{cm} long and sparingly branch. They have a 4-archic central cylinder with central vessel, endo-

dermis with feeble V-thickenings, and a narrow cortex. They show nothing peculiar, and are purely nutritive.

The daughter tubers, however, behave differently. After having formed two or three thin roots of the structure of those just mentioned, each of them sends out one thick, fleshy, contractile root (*fig. 15*, r^1). This root grows in a strictly horizontal direction, keeping in its whole extent not far from the surface of the soil. It reaches over 20^{cm} in length and 3 to 4^{mm} in diameter, tapering in its terminal portion to 1^{mm} in thickness. Its central cylinder is 5-archic with a central vessel, and the cortex is very thick.

It is semi-transparent, and it can be seen that the course of the central strand is not straight, but irregularly undulated and spiral (*fig. 16*). Such a course of the central strand is very uncommon in monocotyledons. Also in this case it seems to be not so much a necessary consequence of the shortening itself, as a consequence of the irregular manner in which the active cortical cells change their form. While in other roots the cortex behaves equally all around the central cylinder, in this case the radial elongation of the cells seems to take place now on one, now on the other side of the root, and the volume of the cortex increases alternately on different sides of the strand. This strange phenomenon, and the manner in which it is brought about, deserves a closer investigation. In consequence of the contraction the membranes of the thin-walled endodermis, as well as of the hypodermis, become undulated, and the root surface wrinkled to an extent of 3^{cm} from the base. No zone of collapsed cortical cells, however, forms. The anatomical peculiarities mentioned disappear near the tip.

The root seems to shorten about 10 or 20^{mm}. From every one of the lateral tubers the contractile root grows toward the outside, turning away from the mother plant. The result of the contraction is that every lateral tuber is pulled out of its husk, which remains on the spot, and is removed horizontally about 10^{mm} (*fig. 15*, t^2). During this process the small tuber, now in a horizontal position, shrivels and forms a new tuber on its top.

In the later part of the rainy season the emptied tuber-portion dies off with all the roots, and the following year the new tuber sends up its leaf about 1^{cm} away from the mother plant. The formation of horizontal contractile roots seems to repeat itself several times in the same individual.

This mode of loosening crowded colonies by the action of horizontal roots occurs, according to Kerner von Marilaun (*Plant Life* 2:769. 1891), also in *Muscari racemosum* and *Ornithogalum nutans*. I have not yet had an opportunity of seeing it in these species. But it is by no means a frequent phenomenon, and does not occur at all in most of the bulbous plants, as Kerner assumes in the quoted passage. From my own experience, contractile roots of strictly horizontal direction seem to be very rare, and therefore their occurrence in Brodiaea is the more noteworthy.

Reviewing the ten species examined, we can state that, although they are geophilous herbs of similar organization, they nevertheless show extremely different modes of burying themselves. From this point of view we may arrange these plants in three groups:

The first group includes Clintonia, Prosartes, and Fritillaria. In these the rhizome alone, by its movement of growth, determines the location of the plant in the earth. It develops horizontally, and is not influenced in a mechanical way by the roots, which are not contractile.

The second group is formed by Lilium, Scoliopus, and Trillium. Here the growth of the horizontally developing rhizome determines in a much smaller degree the location of the plant. In general the influence of the contractile roots prevails in fixing the position of the rhizome.

The third group contains Zygadenus, Chlorogalum, Calochortus, and Brodiaea. In these the rhizome develops vertically, and the contractile roots determine almost exclusively the position of the plant.

Furthermore, we find that in Clintonia, Prosartes, Fritillaria, Lilium, Scoliopus, Trillium, and Zygadenus the roots are all of

the same kind and differ but slightly; whereas in Chlorogalum, Calochortus, and Brodiaea there takes place a division of labor between nutritive and contractile roots, accompanied by a striking difference in form.

Finally, considering the age the roots may attain, we see that it amounts to many years in Clintonia, Prosartes, Scoliopus, and Trillium, and to a few months only in Fritillaria, Zygadenus, Chlorogalum, Calochortus, and Brodiaea. Contractility is found not only in long-lived roots, but also, and in a very high degree, in short-lived ones. Long-lived roots assume also the function of storing reserve material; they may be contractile (Scoliopus, Trillium) or not (Clintonia, Prosartes). In those species which during a certain time of the year are rootless the roots never seem to be used as storing organs.

SAN FRANCISCO, CAL.

EXPLANATION OF PLATE XIV.

All figures are drawn from nature, and where not otherwise indicated are natural size. The horizontal dotted lines indicate the surface of the earth. All the figures are in the natural position and distance with regard to these lines.

Scoliopus Bigelovii.

FIG. 1. Seedling: *s*, seed; *c*, cotyledon; *r*, root.

FIG. 2. Half-grown, descending specimen, at the end of January: *rh*, rhizome; *r*, fully developed roots of former year; r^1, new developing roots; *st*, aerial stem.

Zygadenus Fremonti.

FIG. 3. Seedling: *s*, seed; *c*, cotyledon; *l*, leaf; *r*, primary root.

FIG. 4. Half-grown, descending specimen, in February: *b*, bulb; *r*, contractile roots of the present year; r^1, remnants of roots of the preceding year, carried down by the movement of the bulb.

FIG. 5. Bulb of full-grown specimen, in March; longitudinal section: *a*, bulb-axis; *st*, aerial stem of the present year; st^1, aerial stem of the preceding year; *r*, contractile roots.

FIG. 6. Endodermis from the basal portion of a contractile root; tangential section. × 200.

FIG. 7. Endodermis from the terminal portion of the same root; tangential section. × 200.

Chlorogalum pomeridianum.

FIG. 8. Seedling: *s*, seed; *c*, cotyledon; *l*, leaf; *r*, primary root; r^1, second root.

FIG. 9. Half grown, descending specimen, in the latter part of January: *b*, bulb; *r*, non-contractile roots; r^1, contractile root of the present year, with the wrinkles appearing at the base; r^2, dead, contractile root of the preceding year, pulled downwards by the movement of the bulb.

FIG. 10. Lower portion of adult bulb; longitudinal section: *a*, bulb axis; *bs*, bulb scales; *st*, aerial stem of the present year; st^1, remnants of the aerial stem of the preceding year; *r*, living root of present year; r^1, dead root of preceding year.

FIG. 11. Cross-section from the basal portion of a contractile root of a young, descending specimen, $\times 5$: *cyl*, central cylinder; *in*, inner (active) cortex; *com*, layer of compressed cells; *out*, outer (passive) cortex.

Calochortus umbellatus.

FIG. 12. Young, descending specimen, in April: *b*, bulb; r^1, contractile root; *h*, husk of the last year.

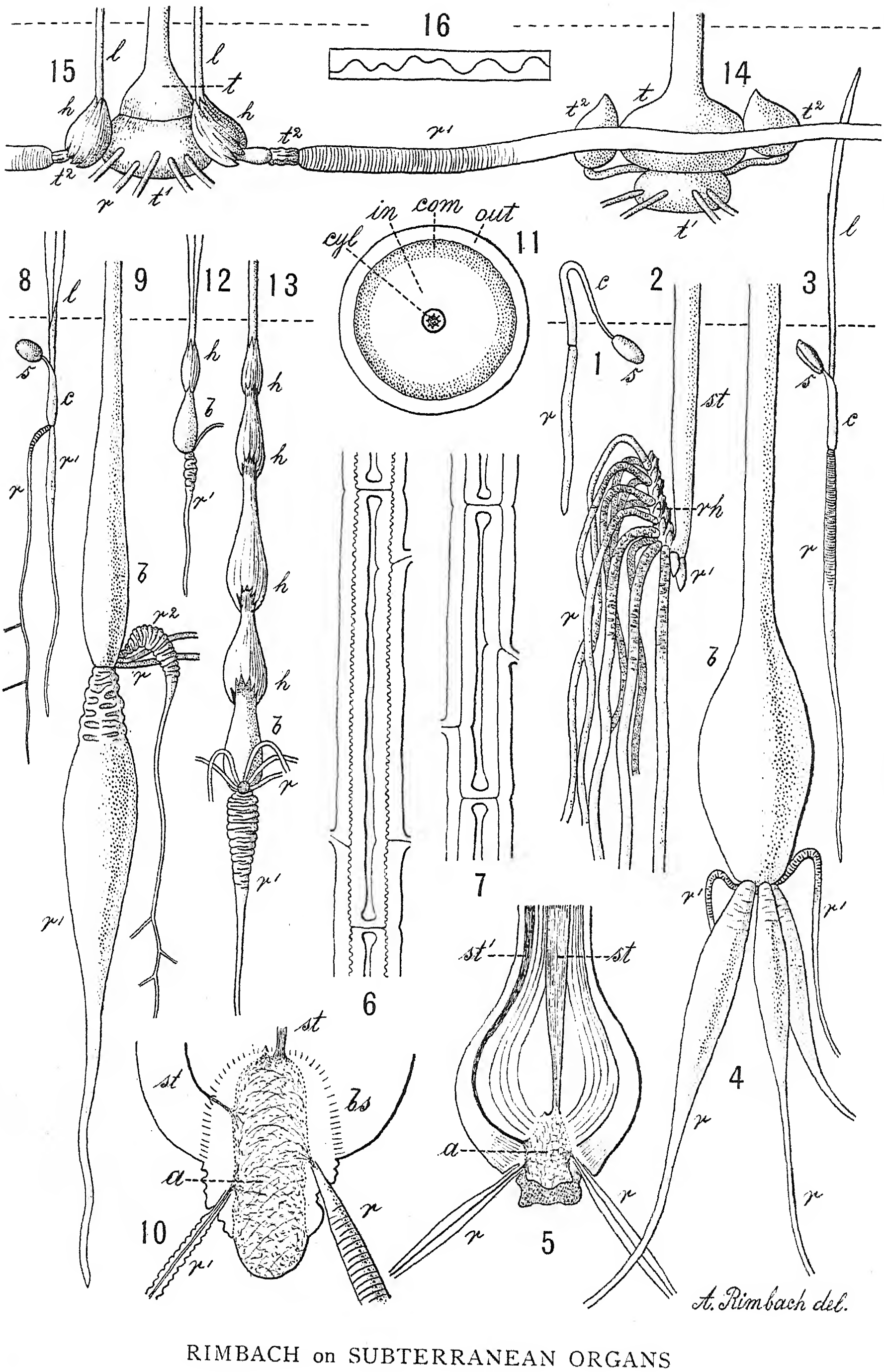
FIG. 13. Almost full grown, descending specimen, in April; the contraction is finished: *b*, bulb; *r*, non-contractile roots; r^1, contractile root; *h*, dead husks of preceding years.

Brodiaea capitata.

FIG. 14. Subterranean parts in March: *t*, newly formed part of main tuber; t^1, old, decaying part of the same; t^2, new, lateral tubers fully developed.

FIG. 15. Subterranean parts in January: *t*, new part of main tuber in formation; t^1, old part of main tuber; t^2, last year's lateral tubers, shriveled and carried away from the mother plant; *h*, dry husks of the same; *l*, leaves of the same; *r*, thin roots of main tuber; r^1, contractile root of lateral tuber.

FIG. 16. Piece of contractile root, showing course of central strand. $\times 2$.



RIMBACH on SUBTERRANEAN ORGANS

THE PARASITISM OF BOTRYTIS CINEREA.

RALPH E. SMITH.

(WITH TWO FIGURES)

THE classic works of De Bary (1), Kissling (3), and Marshall Ward (2) were the first to call attention to a mode of parasitism in fungi which had not previously been recognized. These investigations brought out the fact that in certain fungi parasitism is brought about by the secretion of a soluble substance by the mycelium which kills and disintegrates the host tissue at a considerable distance from the filaments, thus affording them practically saprophytic nourishment. This substance was thought by each of these investigators to be of the nature of a soluble ferment or enzyme, possessing the power of dissolving cellulose, whereby the injurious effect. Without detracting from the value of these investigations, it may be said that from more recent works on the subject it is evident that there is still much to be explained in regard to the phenomena which these earlier writers described.

The fungi to be considered in this connection form a closely related group which may be designated as the Botrytis-Sclerotinia type. *Botrytis cinerea* has been chosen as the subject of the present article, but the related *Sclerotinia Libertiana*, the subject of De Bary's work, as well as other forms of Botrytis of the *cinerea* type, come naturally into consideration.[1]

As a saprophyte no mold is more generally prevalent than *B. cinerea*, but to the pathologist this species is of special interest on account of its peculiar relations to the phenomena both of saprophytism and parasitism. It is, in a general sense, an example of the facultative parasite of Van Tieghem and De Bary, or the hemi-parasite of Von Tubeuf; the term *Gelegenheits Parasit* of the latter writer describes it more accurately. Briefly

[1] See no. 13 in the list of literature as to the genetic relation of these forms.

stated, the usual conditions under which this organism may affect living plants are as follows: excessive moisture, stagnant air (these two especially when combined with high temperature), low vitality of the host plant, and upon young or delicate parts of plants. While not covering all cases, the parasitic attacks of Botrytis may almost always be ascribed to one or a combination of these conditions. (A number of typical cases of Botrytis attacks are described or referred to in the writer's previous article.) All degrees of parasitic activity occur under these favorable conditions, from growth upon ripe fruit, where the fungus is scarcely more than a saprophyte, to vigorous development upon live growing tissue.

Generally stated, this species is disseminated by means of its conidia, which germinate upon parts of plants and send germ tubes into the living tissue, where they spread about, causing death and disintegration. Kissling found that, unless germination started with saprophytic nourishment at hand, no infection took place, a peculiarity previously discovered by De Bary in *Sclerotinia Libertiana.* Potter (8) found, however, that living tissue could be affected directly with conidia in water. Marshall Ward also found direct infection possible in the form of Botrytis which he investigated. The variation in this respect expressed by these results has been found by the writer to be a constant one. With some material direct infection could be produced in a moist chamber, while at other times such attempts were unsuccessful. In all cases much more active infection took place when saprophytic nourishment was used as a starter. The conclusion therefore seems justified that Botrytis varies in the ability of its conidia to produce directly parasitic germ tubes, but with a general tendency to require a saprophytic start.

After infection has taken place, the affected tissue becomes softened and dead and rapidly disintegrates. In the case of fleshy substances, such as turnips and carrots, it is noticeable that, as long as no other organisms become abundant, no disagreeable odor whatever is produced, even when the tissue is thoroughly permeated by the fungus. In *fig. 1* is shown the

characteristic effect of Botrytis filaments upon vegetable tissue, as seen under the microscope. Here is represented a filament of Botrytis growing in the petiole of a lettuce leaf, a soft, succulent tissue. The effect is seen to be a darkening in color, loss of turgidity, disintegration of protoplasm, a separation of the cells from one another, and their final collapse, the tissue being affected considerably remote from the filaments. The same effect is seen in the vicinity of a germ tube penetrating the surface. To the naked eye affected tissue is found to be softened and disintegrated, having the appearance of being boiled. From the nature of this effect it is evident that such a fungus as this is not in a strict sense a parasite. That is, it does not live directly upon living tissue as, for example, the Uredineae, but rather subsists strictly upon dead and disintegrated plant substance. Its parasitism consists in its ability, limited to the conditions already enumerated and varying greatly in intensity, to secrete a substance which has a toxic effect upon living tissue. The nature of this substance may now be considered. Marshall Ward brings out the idea that the filaments secrete a cellulose-dissolving enzyme, which attacks the cell walls and transforms their substance into available food material for the fungus. Kissling records the same result. De Bary showed the same to be true in the case of the species which he investigated.

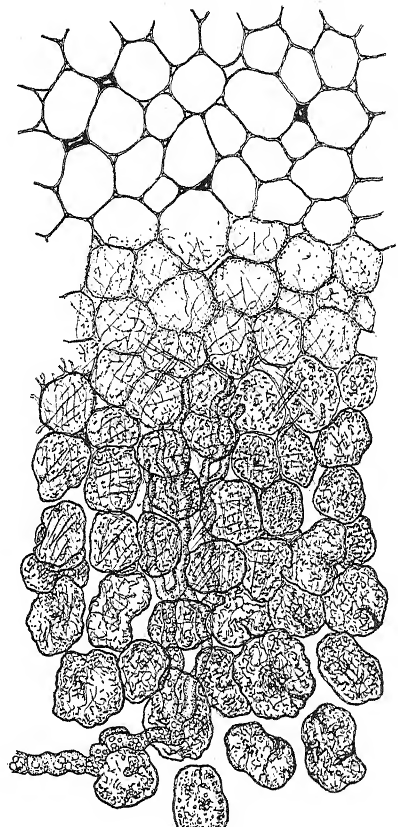


FIG. 1.—Filament of *Botrytis cinerea* invading the tissue of a lettuce petiole.

According to the first author, a watery extract of Botrytis mycelium caused, in thin slices of vegetable tissue, a dissolving of the middle lamellae and strong swelling and final dissolution of the cell walls. When such extract had been previously boiled no effect appeared. No statement is made as to any definite effect upon the cell contents. Kissling also assumes that a cellulose enzyme is the sole cause of the destructive effect. De Bary reaches the same conclusion in regard to *Scl. Libertiana*, but not without some apparent misgivings. At one point (p. 418) he says: "By a single brief boiling the juice [mycelium extract] loses its specific poisonous effect," but again (p. 421) "the difference [between the effects of boiled and unboiled extract] is to be sure a quantitative one so far as can be observed. . . . . With the liquid from sclerotia the same differences appear, though less prominently; the boiled has here a relatively greater effect." Behrens (10) found that boiling an extract of Botrytis mycelium did not destroy its injurious effect upon plant tissue.

It seems reasonable to suppose that a watery extract of the mycelium of this fungus should contain any soluble substances secreted by the filaments, and have the same effect upon tissues, so far as enzymes and any other soluble substances are concerned, as the fungus itself. In preparing such extracts the writer has made use of the following method: Large flasks of any good liquid medium, usually prune juice, were prepared and sterilized, and then inoculated with Botrytis. A vigorous mycelium soon developed upon the surface, which was removed and washed, then cut up into small fragments and finally ground to pulp in a mortar with clean quartz sand. This pulp was then placed in water, and allowed to stand in a warm place for several hours, after which the clearer portion was decanted off, thus getting rid of the sand, and strained. When vegetable tissue was placed in such an extract the effect was very similar to that produced by the growth of the fungus. If a lettuce leaf was placed with the petiole in a flask of the extract all the tissue in contact with the liquid became softened and discolored, and soon

disintegrated, just as in a leaf with the fungus actually growing in the petiole. In a thin section placed in this substance the cells underwent the characteristic changes shown in *fig. 1*, except that more plasmolysis took place. Apparently, therefore, the toxic principle of this fungus is a soluble substance given off by the mycelium.

It was especially noticeable in these tests that the marked swelling of the walls described by Marshall Ward did not occur. No change whatever could be detected in this respect. Behrens and Nordhausen (12) also found this to be true with *Botrytis cinerea*, while De Bary's casual mention of a slight swelling can hardly be construed to denote the highly characteristic effect described by Ward. Potter (9) found apparently the same effect produced by bacteria. The writer has found no marked change produced by boiling the extract. Certainly the softening of the tissue and death of the cells resulted as before. It is evident, therefore, from the last result alone, that the effects of this fungus upon plant tissue are not entirely due to an enzyme.

The study of the subject has led the writer to the conclusion that two different effects must be clearly distinguished, one following the other: first, the death of the cells; and second, the disintegration of their walls and contents. The further conclusion has been reached that the first effect is produced by a poisonous substance, not an enzyme; the second by a variety of enzymes not necessarily always the same, each affecting its particular substance. The latter conclusion has been deduced from the results of a large number of cultures, made to ascertain the ability of Botrytis to thrive upon various substances of vegetable origin, likely to occur in plants. For this purpose there was first made up a normal mineral-peptone solution, according to one of the usual formulæ, and to portions of this stock solution were added the various substances to be tested, and flask cultures made in the usual manner. These substances may be taken up separately.

Starch.— It was found impossible to grow Botrytis upon this substance, although Behrens states the contrary. In the first

experiments a medium was made up by adding 2^{gm} of commercial cornstarch to each 98^{cc} of the stock solution. The starch did not dissolve to any great extent, but formed a paste. Inoculated with Botrytis only a very feeble growth resulted. From this it seems that this species has not sufficient power of hydrolizing starch into a form of sugar in which it could be assimilated to provide for its full development. It was found, however, that in a very dilute starch solution hydrolysis could be brought about by adding an extract of the Botrytis mycelium, as shown by the iodine test. From this it appears that the fungus secretes at least a small amount of diastase.

Dextrose (glucose, grape sugar).—A 3 per cent. solution of this substance in the stock solution was used as a culture medium. Growth was rapid, and development luxuriant, as was to be expected.

Cane sugar.—A solution containing this substance was made as in the last case. Growth was at first slow, so that at the end of the first week the dextrose cultures were much ahead. Gradually, however, the development became more vigorous, and the final result was as good as any. This course of development gave reason to suppose that it was first necessary to invert the cane sugar before it became available, and that the fungus possessed the power.

Milk sugar (lactose).—The results with this substance were very similar to those with the last; a rather slow start, but eventually a vigorous development.

Maltose.—Vigorous growth from the first.

Levulose (fructose).—Same as last.

Galactose.—Good growth.

Dextrin.—Growth in this substance started rather slowly, but soon became as good as any.

Inulin.—In a 4 per cent. solution of inulin in the stock solution only a very slight growth of Botrytis could be obtained. No normal development whatever took place.

Glycerin.—With 2 per cent. glycerin in the stock solution very good development took place.

Gum arabic.—A similar result to the last was obtained with 4 per cent. gum arabic.

Cellulose.—Cultures were made by using the purest obtainable cellulose, in the form of filter paper, mixed into a pulp with the stock solution. An excellent growth took place in this medium, showing that the fungus was able to utilize cellulose as a food material. Behrens obtained similar results.

Linseed oil.—A 4 per cent. solution of this substance was made in the stock solution. This naturally formed a layer upon the surface, but by frequent shaking the oil was kept mixed with the other liquid for a considerable portion of the time. Growth in such cultures was very good, and a normal development took place. The solution gradually became darker in color until nearly black, while the oil lost its characteristic appearance and the dark colored liquid became homogeneous in appearance.

Cottonseed oil.—Similar results to the last were obtained with this substance.

Tartaric acid.—Two grams of this substance in the dry form were added to 98^{cc} of the stock solution. Growth was excellent throughout.

Malic acid.—With a similar solution of this substance a very vigorous development was obtained.

Oxalic acid.—With this substance in the same proportion no growth whatever appeared.

Formic acid.—To 98^{cc} of the stock solution 2^{cc} of 98 per cent. formic acid was added. No growth appeared.

Tannin.—A 2 per cent. solution of commercial tannin was made with the stock solution. Growth was excellent, the solution slowly turning black.

Asparagin.—With a 1 per cent. solution of this substance in the stock solution, a very quick growth appeared, developing conidia more quickly than in any other culture. Subsequent growth was not very vigorous.

Salicin.—With a 1 per cent. solution of this substance growth was very slow, but in time reached a fairly vigorous development.

Amygdalin.—In a 2 per cent. solution of amygdalin growth was slow and only fair. The odor of almonds became noticeable in the culture after some development had taken place.

Brucin and strychnin.— In 1 per cent. solutions of these poisonous substances growth was extremely feeble and practically nothing.

Quinin and thein.—In 2 per cent. solutions of these substances no growth took place.

It appears, therefore, from the above results that *Botrytis cinerea* is able to satisfy its carbon requirements from the following substances: sugars in general, dextrin, cellulose, glycerin, gum arabic, vegetable oils, tartaric and malic acids, asparagin, and several glucosides, as tannin, salicin, and amygdalin. The effect of the growth of the fungus upon these substances may now be considered. In studying this point the method used was to reserve a portion of each solution tested, which could later be compared with the remainder of the solution, upon which Botrytis had developed.

SUGARS.

No extensive study was made of the complicated transformations of the various sugars which take place under such circumstances as these. The Fehling test showed that in all cases the solution upon which Botrytis had been growing gave a strong reduction, so that in the case of cane sugar inversion had taken place. It was found that oxalic acid was produced in considerable amount from the sugars, presumably by oxidation, and occasionally traces of acetic acid. Alcoholic fermentation was carefully looked for, but no trace of this substance could be detected in the distillate from the culture fluid. The specific effect of the growth of the fungus upon dextrin, cellulose, glycerin, gum arabic, asparagin, and acids, was not studied. The same is true in regard to the vegetable oils, except that the darkening in color and disappearance of the distinct nature of the oil was apparent to ordinary observation, showing that an important change took place.

TANNIN.

The effect of the growth of Botrytis upon commercial tannin was quite closely followed. It has already been mentioned that the liquid gradually became of a darker color and finally nearly black. The same effect could be shown by mixing a 2 per cent. solution of tannin in a flask of gelatine. A flocculent precipitate occurred, giving the hardened gelatine a white color. When inoculated with Botrytis this color began to disappear about the point of inoculation and turn brown. Gradually the change spread, keeping pace with the growth of the organism, until finally the whole mass of gelatine to a considerable depth had this dark color. This is an excellent method for showing this reaction.

A solution of tannin in the stock solution was divided into two portions and one inoculated with Botrytis. After the end of one week the latter was dark brown in color, while the original portion was still nearly colorless as at first. Both gave a deep purple precipitate with ferric chloride. With calcium hydrate the original solution gave a white precipitate, changing to lilac (tannin reaction.) That upon which Botrytis had grown gave a heavy precipitate, the color of which could not be clearly distinguished on account of the dark color of the liquid. Another portion of the Botrytis liquid was agitated with ether, and the ether then poured off and tested with calcium hydrate. This gave a brown precipitate rapidly darkening (gallic acid reaction). A solution of gelatine gave with the original tannin solution a heavy white precipitate. With the culture fluid no precipitate appeared. After adding an excess of gelatine to both solutions they were again tested with ferric chloride. The original liquid gave no reaction, all the tannin having been precipitated. The other still gave the deep lilac reaction. It was therefore shown plainly that the tannin had been decomposed by the fungus, and that gallic acid was one of the products of decomposition. To portions of each liquid calcium hydrate was added till no further precipitate occurred. These were filtered, and portions of the filtrates tested with ferric chloride until solutions were obtained

entirely free from tannin and gallic acid. With the original solution the final filtrate was perfectly clear. The culture liquid still retained its dark color. These filtrates were then tested with Fehling's solution for sugar. The first gave no result. (It was necessary to remove the tannin, as the substance reduces copper.) The culture fluid gave a strong glucose reaction. These results show therefore that Botrytis decomposes commercial tannin into glucose, gallic acid, and a dark coloring matter whose nature was not further investigated.

SALICIN.

The culture fluid containing this substance was tested with ferric chloride for saligenin, which was always found to be present, though in small amounts. It has previously been mentioned that growth upon this substance was very slow. Apparently the usual decomposition of salicin into saligenin and glucose is effected by Botrytis.

AMYGDALIN.

It has been mentioned that after the growth of the fungus upon this substance was under way, an odor of almonds could be easily detected, which was not apparent in the original solution. This indicates the decomposition of amygdalin into glucose and hydrocyanic acid.

It may be assumed in a general way that these changes in the nutrient media are brought about by the corresponding enzymes, which are secreted by the fungus. It has not been considered necessary to the present discussion to attempt to isolate or study these individually, though this organism is well adapted to such a study. The method of treating substances to be tested with an extract of the mycelium is to be used as a basis for such work. (The citations in Green's work, especially those on the work of Bourquelot and his associates, will be found instructive.) The results of the cultures show in general that this fungus is able to avail itself of most of the ordinary constituents of vegetable tissues when unprotected by vital activity.

The cellulose enzyme calls for especial mention on account of the prominence which has been given to it. It appears to the writer that the discrepancy between the results of Marshall Ward and those of Behrens, Nordhausen, and himself in this respect is to be explained by the varying composition of the substance broadly called cellulose, and the varying ability of fungi to dissolve this substance. In all cases it appears that the more easily affected forms, the hemi-celluloses and pektoses, forming the middle lamellae, etc., were dissolved. That the fungus studied by the writer is able to affect, to some extent, true cellulose, is evident from the cultures on filter paper; but in the case described by Ward, and also that by Potter, where a strong swelling of the cell wall was produced, the most rational explanation seems to be that an entirely different enzyme was present. (See Newcombe (11) and Green (14), p. 84, on the general subject of cellulose enzymes.) But, however this may be, the point seems clear that the cellulose enzyme or enzymes are subordinate in effect to some toxic substance of a different nature. The effect of the boiled mycelium extract, plasmolyzing and killing the cells with which it comes into contact, is enough to show this. Furthermore, the cellulose enzyme idea of Ward and Kissling allows no explanation of the first entrance of the germ tube through the cuticle. The former says (p. 354) "the tips of the germ-hyphæ attached themselves to the surface of the cuticle, and then *dissolved* their way in, discoloring and destroying the cell walls and cuticle in the immediate neighborhood." It would plainly be impossible for the same enzyme to attack both cellulose and cutin. Again it may be stated, that the *death* of the affected tissue is distinctly a different phenomenon from its utilization by the fungus as food. What then occurs?

There can be no reasonable doubt that some soluble substance produced by the fungus diffuses through the cuticle and cell walls and kills the cells some distance ahead of the filaments. Following this, the filaments, probably under the influence of chemotropism, invade the lifeless tissue in all directions, mostly

by simple mechanical pressure aided by cellulose or pektose-dissolving enzymes. It has not been the writer's observation, however, that the filaments penetrate to the interior of the cells to any great extent. Occasionally a case is seen as shown in *fig. 2*, but here there appears to be no dissolving or swelling of the wall, but a breaking through by simple mechanical pressure. The various other enzymes then become active and the tissue is completely destroyed.

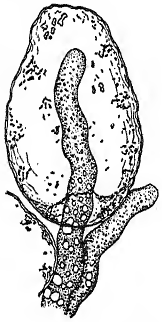


FIG. 2.—Filament of *Botrytis cinerea* penetrating a cell.

The question still remains as to the nature of the poisonous substance. It has already been mentioned, and is a well known fact, that the formation of oxalic acid almost invariably accompanies the growth of Botrytis, being brought about by the oxidation of carbohydrates. Analysis of the mycelium extract also shows this substance in considerable amount. DeBary considered the possibility of this substance being concerned in the effect of the fungus upon vegetable tissue, but discarded the idea on the ground that solutions of pure oxalic acid do not give the entire characteristic effect of a Botrytis extract or culture. The constant occurrence of this substance has seemed to the writer at least suggestive, and its effect upon plant tissues has been studied to some extent. It is of course well known that oxalic acid causes plasmolysis and death of cells if sufficiently strong.

Lettuce leaves were placed by the writer with the petioles submerged in Botrytis extract, and 0.125 per cent., 0.5 per cent., and 1 per cent. oxalic acid. After a few hours of this treatment a remarkably similar effect was observed. All showed marked softening of the tissue where touched by the liquid, followed by collapse and shriveling. The effect of the weakest solution of the acid, 0.125 per cent., was as marked as that of the extract. The boiled extract showed no appreciable difference in effect to the eye from the unboiled. In all five cases the affected tissue had exactly the appearance of having been boiled. The chief

difference in appearance was that the acid had a bleaching effect upon the tissue, while that in the extract became darker colored. Microscopically some similarities and some differences were noted. The cells in the acid were strongly plasmolyzed and killed. In collapsing they pulled apart from one another, so that even in the 0.125 per cent. solution the tissue was almost as completely macerated as in the Botrytis extract. It may be stated conservatively that in a 0.125 per cent. solution of oxalic acid the death of the cells and consequent softening of the tissue was fully as marked as in an average Botrytis extract. The cell wall was somewhat swollen in the acid, but not in the extract. The disintegration of the protoplasm was more marked in the extract. De Bary found in a sample of Sclerotinia extract 0.319 per cent. oxalic acid. The writer has found over 2 per cent. in the mycelium extracts from old cultures to which sugar had been abundantly supplied. It can therefore scarcely be doubted that in such an extract the acid alone would have a marked effect upon plant tissue, whether or not the liquid had been boiled. It is, however, a reasonable objection to judging the effects of the growth of the fungus by those of such extracts, that with germinating conidia or filaments rapidly advancing into new tissue no such amounts of oxalic acid could be expected to accumulate. It is therefore necessary to consider the effects of much more dilute solutions.

Solutions of 0.01 and 0.05 per cent. were prepared, and their effects upon vegetable tissue studied as before. When thin sections of lettuce petioles were placed in these weak solutions, together with others in pure water, the effect was still strongly marked. Within a few minutes a bleaching was evident, and soon the green color had entirely disappeared. Plasmolysis did not occur, but an effect almost identical with that shown in the most newly affected tissue in *fig. 1* soon developed. Especially noticeable is the granular appearance of the affected cell contents, particularly near the walls. Whether this is due to the deposit of an insoluble oxalate, or to a change in the protoplasm, is difficult to determine. However this may be, it appears that

the cells are killed by poisoning, without plasmolysis, both by the fungus itself and by very delicate solutions of oxalic acid, while with the stronger solutions obtained in mycelium extracts or made up directly with the acid the same effect is accompanied by plasmolysis. The softening and bleaching effect of the acid even in 0.01 per cent. solution was very evident to the naked eye.

The production of gallic acid from tannin by the growth of Botrytis has been described above. In a 1 per cent. solution of this substance a lettuce leaf petiole became softened and collapsed much as in the Botrytis extract, but more slowly. A dark color was produced much as in the extract, rather than the bleaching by oxalic acid.

It seems to the writer that we have to seek in some such explanations as these the cause of the poisoning and death of the cells of tissues attacked by Botrytis. Most of those who have considered the subject before seem to have overlooked the fact previously stated that two distinct effects are brought about by the fungus, and that no one substance can produce both of these. That the first or poisonous substance is not an enzyme is plainly proven. That it is oxalic acid seems more than probable from the regular occurrence of this substance and its described effects. The discoloration of the cell walls which the fungus produces, rather than the bleaching brought about by a solution of oxalic acid, is readily explained by the decomposition of tannin or some similar compound.

There may now be considered briefly, in the light of this theory, the tendency in this species to require saprophytic nourishment preliminary to its parasitism. If spores of Botrytis are sown in water upon living tissue no infection ordinarily results. If a drop of prune juice or any good nutrient be added, infection often takes place, under the conditions previously enumerated. This is explained in a general way by the statement that the fungus acquires *vital energy* or *vigor*, by such nourishment. Expressed more definitely, the idea has been that the production of the cellulose-dissolving enzyme is stimulated by this

means, and that the varying ability of the fungus to infect directly depends upon a varying power of enzyme formation from the reserve material of the conidia. The theory advanced in the present article is easily adapted to the known conditions in this respect. The addition of a nutrient solution would at once bring about the formation of oxalic acid, poisoning the subjacent tissue and permitting the entrance of the hyphae through the dead cuticle and epidermis by mechanical force under the influence of chemotropism. That this effect would be favored by the conditions under which Botrytis attacks living tissue needs no explanation; thickness of cuticle and epidermis, and vital activity of the host being the most potent controlling factors. Without such nourishment the ability of the germ hyphae to enter the plant depends upon the amount of acid formed from the reserve material in the conidia. In the linden and rose diseases studied by the writer (13) the conidia formed were found to be of unusually large size. Marshall Ward found in the lily disease, where infection took place as well without saprophytic nourishment as with it, that the conidia were much above the ordinary size, and observation in general shows that where Botrytis grows actively and luxuriantly upon living plants the conidia are very large. Are not these points suggestive of an increased power of infection due to the increased amount of reserve material?

SUMMARY.

Briefly stated, the main point of this article is as follows:

In the best known works upon the parasitism of Botrytis and similar fungi too much importance has been ascribed to a cellulose-dissolving enzyme. Two stages in the process should be clearly distinguished: first, a poisoning and killing of the cells; and second, their disintegration and utilization as food by the fungus. The first effect appears to be produced by a substance which there are strong reasons for supposing to be oxalic acid, formed by the fungus as a by-product of its metabolism. Following this, a number of different enzymes are secreted which digest the various constituents of the tissue. The identity of

these enzymes probably varies somewhat in different cases, and apparently more than one occurs which affects different forms of cellulose. The substance causing a marked swelling of the cell wall in the lily Botrytis, studied by Ward, and the turnip bacterium by Potter, appears to be an enzyme not ordinarily produced by *Botrytis cinerea.*

In conclusion, it may be remarked that these results have a very suggestive bearing upon the parasitism of many other fungi which bring about a rapid destruction of the host tissue.

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THE DEVELOPMENT OF VEGETATION IN THE MORAINAL DEPRESSIONS OF THE VICINITY OF WOODS HOLE.

CHARLES H. SHAW.

(WITH SIX FIGURES)

FEW regions afford better opportunity for observing the stages in the history of small swamps than the vicinity of Woods Hole, Mass. The land of the neighborhood, a few outcrops of Cretaceous strata excepted, consists of the eroded mass of a terminal moraine. Clay, sand, and fragments of stone grading up to huge bowlders constitute the country rock. Indenting the surface of this mass of débris are innumerable specimens of the peculiar depressions known to geologists as "kettle holes." In such hollows ponds and lakes have formed, each one the first term of a long series ending in its own obliteration. The changes by which the pond is destroyed, and in which vegetation plays so important a part, furnish a subject of absorbing interest. Many workers have gone far toward giving us an understanding of such a history. However, our knowledge is not complete, and questions which arose in the work at the Marine Biological Laboratory have led to this attempt to answer them. The present paper may be conveniently divided into three sections.

PHYSICAL FACTORS—EROSION AND DEPOSIT.

The authors who have pointed out the interesting and important part played by vegetation in the filling of ponds have possibly minimized the purely physical factors. At times the latter play a leading, and at times, as in cases mentioned later, an exclusive part.

The amount and the character of the silt washed down varies greatly with the nature of the surrounding surface. Where the latter has been disturbed by man, the quantity of material brought in, even by summer rains, is often astonishing.

Fig. 1 shows a pond in the edge of the village, adjoining a road. On July 2 there was a thunder shower lasting for about an hour. During that time a deposit was formed at one corner of this pond some $25^{sq.\ m}$ in area and $30–90^{cm}$ in depth. Four weeks later came another, less violent shower. The surface of the first deposit was cut down part way across by $40–50^{cm}$, and

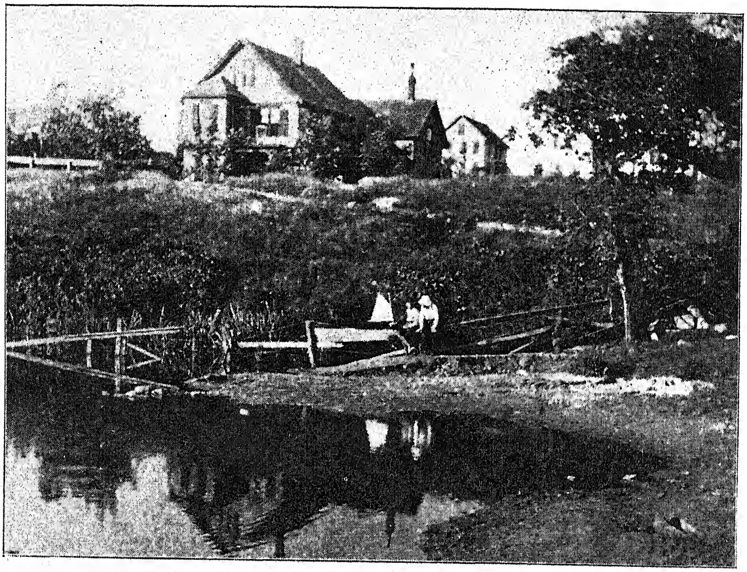


FIG. 1.—Pond in edge of village.

the material, aggregating many tons, borne farther out. The obliteration of this pond within two or three years may be expected. Of course, we are here dealing with highly disturbed conditions, but nevertheless the case may serve to enlarge our ideas as to the rapidity with which silt may be moved down. During the early period immediately following the retreat of the glacier, and before vegetation gained a footing, deposits in these depressions must have been made with enormous rapidity.

Where the pond is surrounded by grassy fields, the washing-in process is much restricted. That it still goes forward, however, one need only examine the pond margin to learn. A zone

of fine earth and sand encircles the pool, pushing slowly inward. If the contour of the surrounding land is such that the rain rivulets cut out a gully, the zone of silt deposit opposite its mouth indents the pond as a sandy or gravelly delta. These borders and deltas of silt become the seat of well-marked plant societies. *Gratiola aurea* in particular occurs with regularity, and its yellow blossoms may indicate to the eye at a distance the limits of such deposits. If the pond is situated in the deep woods, results are produced which are apparently paradoxical, and will be discussed below.

NOTES UPON SUCCESSIVE STAGES.

Large holes present, of course, the earliest phases, and in the small ones the more advanced conditions are found. As a type of the former we may chose Long pond, near Falmouth village. It is about 2½ kilometers long, and reaches a depth of 28 meters. The shores are of the usual morainal materials, and in some places precipitous. As usual in such cases, it is without drainage, yet its depth and area are such that its water is well aerated, and, as analyses have shown, is nearly free from organic matter. The scanty vegetation admits of being described with some exactness. In the body of the pond no plants are seen. Near the shore appear some filamentous algae, and four species of flowering plants. The latter are distributed in two zones, sharply and surprisingly separated by one destitute of vegetation.

Limnanthemum lacunosum forms a continuous belt, but one which *never touches the shore line*. Soundings taken all around the lake show that the Limnanthemum zone is here confined to water between 0.6 and 3.9^{m} in depth. These soundings were made in August, when the water was about 20^{cm} lower than the line seen on the rocks. Limnanthemum, then, is here able to anchor on the bottom and float its leaves in water somewhat exceeding 4^{m} in depth. *Lobelia Dortmanna* appeared in about the same zone, growing entirely submerged, and could be seen from the surface through the transparent water. For obtaining specimens a bathing suit was useful. Many of the plants had put forth long scapes

at the time, but these could not reach the surface, and the blossoms decayed without opening. Like the preceding species, this did not occur in the shallow water next the shore line. *Gratiola aurea*, in its strictly hydrophilous form, was found in company with these also, but did not appear to flourish.

Between the zone of these three plants and the shore line was a space of open water, devoid of phanerogamic vegetation.

On the shore line, its roots submerged, *Euthamnia* (*Solidago*) *graminifolia* appeared, and its rich border of bloom nearly circuited the pond. That the zone of Limnanthemum and Lobelia did not extend inward till met by Euthamnia seemed a circumstance needing explanation, especially since both the former flourish elsewhere in very shallow water.

At some points wave-marks on the bottom had been seen, and it was noticed that the outer limit of these coincided with the shoreward limit of the Limnanthemum zone. Sandy silt in some quantity was coming in from the surrounding slopes. Limnanthemum plants along the shoreward margin of the zone were found buried in sand at the bottom, and dying. There seemed then reason for believing that the shoreward limit of this zone was set by the action in shallow water of the wavelets in shifting the silt, and burying the bottom-growing vegetation.

Fig. 2 is a graphic illustration of action of this sort, drawn from a large pond on an adjacent island, called West end lake. Silt is coming into the pond from the low surrounding hills. At one spot a great bowlder, out from the shore line, breaks the wavelets, and the silt has run out to it as a sandy peninsula whose curving sides represent the hyperbola of the broken wave action. Thus the outlying bowlder plays a rather fantastic part in the growth of the land, and shelters a certain area from the smothering action of material which comes from the shore. The nearly clean, sandy bottom of the margin of this lake is due to the fact that the shallow water vegetation is constantly overwhelmed by the encroaching silt. Sheltered behind the bowlder, a colony of *Juncus militaris* is growing.

At Long pond, Euthamnia, nevertheless, grew just at the

shore where the danger of burial was greatest. Explanation of this fact was found by digging, for the plant possessed running stems, penetrating the sand in all directions in a manner similar to sand binders, and like them was able to grow out as fast as buried. Limnanthemum and Lobelia have no runners, and so are driven to the zone beyond.

At the south end of Long pond, the slopes surrounding are of

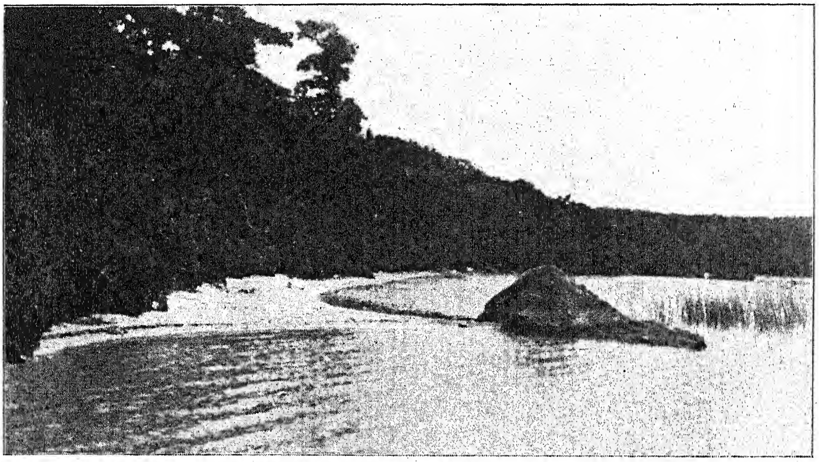


FIG. 2.—West end lake.

such a contour that washings would be swept toward a certain portion of the shore line. Moreover, the surface near this portion has been broken by cutting a road, and silt is brought in great quantities. Where this material reaches the shore line a sandy beach is formed, and from the beach it has advanced into the pond some 30 meters as a submerged delta. The diagram (*fig. 3*) may aid in making the case clear. The outline of the delta is shaded ; the sandy beach represented by the line *a–b*. Now the Limnanthemum-Lobelia zone (indicated by the small circles) follows closely the outline of the submerged delta, and the Euthamnia zone on the shore (outlined by the scroll) is interrupted by the sandy beach. The fact is that the former

zone is driven outward by the advancing silt, and the latter interrupted altogether, despite the running stems of Euthamnia. Rowing around above the edge of the delta, and looking down through the transparent water, one can see colonies of Lobelia growing in the little hollows around the margin of the deposit. If the latter should advance, the fate of these colonies is easy to predict.

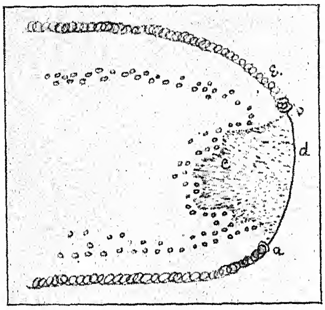


FIG. 3.—Diagram of south end of Long pond.

Fig. 4 is from a photograph taken from *c*, and including the shore line from *d* to *e*. From *d* to *b* may be seen the sand beach, from *b* to *e* a portion of the Euthamnia zone, which continues unbroken a kilometer or more from that point.

Somewhat more advanced than that of Long pond is the stage of a pond near by. The latter is smaller, and analyses here show a considerably greater proportion of organic matter. Portions are shallow, and in such Nuphar and Pontederia are making dense beds. Along the margin Euthamnia finds the space disputed by *Lysimachia stricta*, Lycopus, and *Coreopsis roseus*. Running subterranean stems are possessed by all these plants, and they are able to defy burial by silt in moderate quantities.

The history of the destruction of the shallow pool has been often described. The encroaching of the plants from the margin, the increase of such plants as Nuphar and Nymphaea in the body of the pool till a footing is afforded for less anchored forms, and the consequent formation of the floating mat, may be here passed over with a few local notes. All stages may be splendidly seen in this region. Among recollections of the summer are vivid ones of trying to reach attractive patches of Xyris or Drosera in bloom, and learning that the apparent ground was only floating mat with ominous depths below.

Nuphar and Nymphaea take an important part in the first

formation of the floating vegetation. When a pond happens to be of nearly uniform depth, of 1^{m} or less, Nymphaea may grow in a luxuriance almost incredible. In such a pool, perhaps 150 meters in diameter, near Succonesset point, water lilies were growing and blooming in such profusion that when it was found in July the surface of the pond seen through the trees gave the

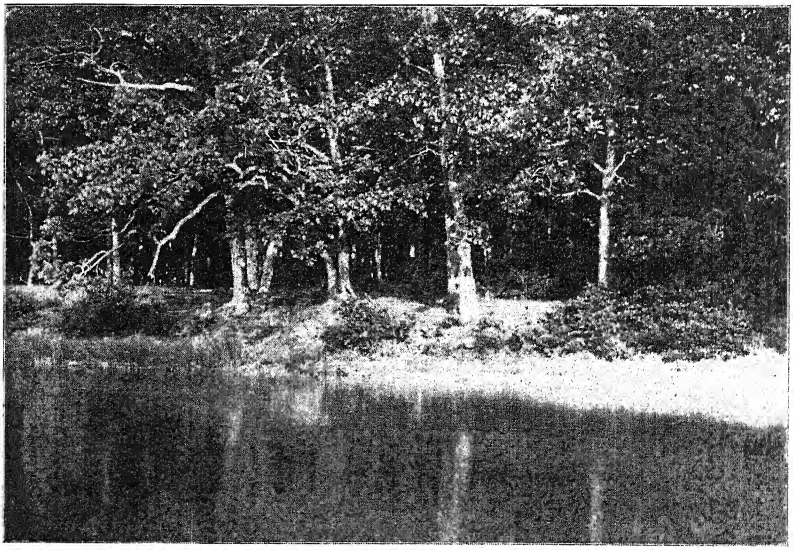


FIG. 4.—South shore of Long pond.

effect of an unbroken sheet of white. Limnanthemum and Brasenia are in some cases important constituents of the first pond vegetation.

In certain places *Hypericum boreale* takes a leading part. This plant shows an interesting dimorphism. It grows submerged as a sparingly leafy unbranched axis, weak and slender, erect by its own buoyancy. When it reaches the surface, however, it breaks out into a strong branching herb, sustaining masses of aerial foliage from enlarged stems floating horizontally on the surface. At Flax pond, in about 30^{cm} of water, it forms thus continuous floating masses many square meters in area.

When such anchored forms, especially the strong ones like Nuphar, gain a good footing, the floating mat vegetation follows apace. Several species of Utricularia aid greatly in this process, by means of their floating and branching tufts. Sphagnum and other mosses, Carices, Xyris, and Drosera appear.

In still further building the mat, and in giving it firmness, *Decodon verticillatus* plays a leading part. Several adaptations give it its preeminence, namely, the firmness of its woody roots and stem bases; its ability, nevertheless, to grow almost floating, only slight support being necessary; and its power of propagating from the tips of its shoots wherever they touch the water. The woody parts mentioned are clothed with thick layers of aerenchyma. Probably this tissue is not only a means of respiration, but also of importance in floating the plant. Decodon occurs almost universally in the yielding ponds.

We have seen that in Long pond, an open lake, the vegetation is purely hydrophilous. About the time of the formation of the floating mat, the general conditions rapidly become xerophytic. Following Decodon, and finding footing on its stools, appear a host of xerophilous shrubs. *Clethra alnifolia*, *Azalea viscosum*, *Vaccinium corymbosum*, *Ilex verticillata*, *Myrica cerifera* and *M. Gale*, *Andromeda ligustrina*, *Leucothoe calyculata*, sometimes Cassandra and others, rapidly transform the floating mat into a swamp thicket. It is observable that these shrubs, though representing widely different alliances, have a certain common facies. All have alternate, simple, lanceolate, nearly entire and nearly smooth leaves.

Decodon passes away before the shrubs, and in due time seedlings of trees begin to appear. As these trees, often wholly Chamaecyparis, grow, the shrubs are overtopped and yield, and the series enters a final cycle as a Chamaecyparis swamp.

Three such swamps in the immediate vicinity of Woods Hole afford beautiful illustrations of these final stages. For the sake of description we may designate them as x, y, and z.

In x the water still stands for most of the year between the stools. Chamaecyparis trees, 10–25^{cm} thick, rise from these

stools, and only close to their bases may the visitor here find footing. Clumps of *Vaccinium corymbosum* and Leucothoe show that these shrubs survive shading better than the other members of the bygone thicket. Between the trees a rod may be thrust

FIG. 5.—Chamaecyparis swamp.

down 5 meters without touching bottom. If one succeeds in making his way to the center, he finds a deep and dark pool perhaps 50 meters in diameter, of whose appearance some idea may be gained from *fig. 5*. On its surface is no vegetation, except a border clinging to the spreading roots of the trees. Long

tufts of *Usnea barbata*, simulating *Tillandsia usneoides*, hang from the trees, and if the beholder is of an imaginative disposition, the weird scene becomes for him a recess of some sub-tropical swamp.

In *y* the water is less in evidence, and sometimes disappears from the surface for many weeks during the summer. The trees average slightly larger. In depressions between their stools Sphagnum is growing; on the stools themselves, thick cushions of other mosses. Shrubs are nearly absent, the lower portions of the trees' trunks are branchless, and one looks through sombre forest aisles, darker and more still than those of a pine forest. No pool is found at its center; matters have gone farther here, and the encroaching vegetation has covered the one time pond completely over.

In swamp *z* water is ordinarily absent, and the ground is firm enough that one may walk where he will. The trees are noticeably larger, some reaching a diameter of 45^{cm}. *Osmunda cinnamomea* grows in abundance. Young cedar trees are scarcely found, and one realizes that he beholds the penultimate term of the long series.

THE ORIGIN OF POND-ISLANDS AND ATOLLS.

In frequent instances the filling-up of the pond takes place in a fashion seemingly paradoxical. Instead of the deposit gradually encroaching from the margin, an island forms in the center and leaves a narrow belt of open water about the edge of the pool.

Fig. 6 shows a case of pond perhaps 15 meters in diameter, near Quisset harbor. That a pond should begin by filling up in the middle is a fact calculated to arouse the curiosity of a layman. The sharpness of the ditch and the frequency with which it appears call for an understanding of its origin. Perhaps it is the same as described by MacMillan[1] in connection with "plant atolls." Yet the hypothesis put forth in the paper cited seems scarcely applicable to the present cases.

[1] On the occurrence of Sphagnum atolls in central Minnesota. Minnesota Botanical Studies 1: no. 9. 1894.

If the pond were larger and deeper than the one shown in *fig. 6*, a pool would remain in the center and we should have a ring of vegetation between the ditch and the central pool. Indeed there is at least one such veritable atoll in the vicinity at present in question, and it is found in a larger basin, perhaps 100 meters in diameter.

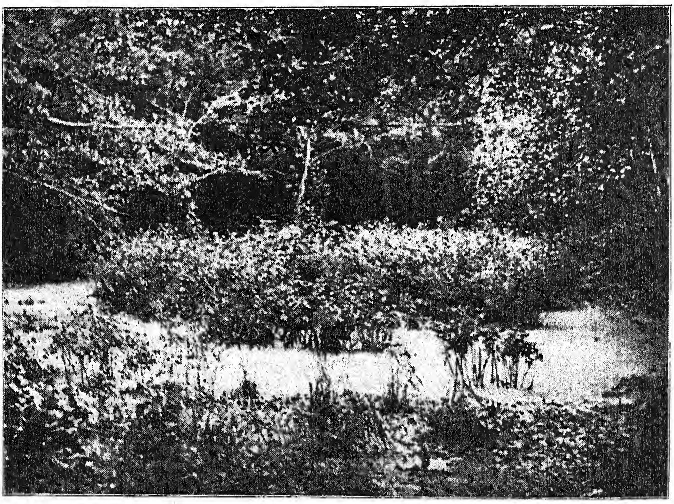


FIG. 6.—Pond-island near Quisset harbor.

The view is here taken that this atoll at least differs from a pond-island only in the fact that a larger kettle-hole is involved, and that in consequence a ring of vegetation is formed instead of an island. The problem would then resolve itself into accounting for the marginal ditch.

Professor MacMillan suggests that the ditch owes its origin to a fall and subsequent rise in the water level of the pond, and the spreading of the water beyond its one time boundaries. In the present cases some facts seem to call for more explanation than this hypothesis affords. The ditches, though perfectly sharp, are quite shallow, having an average depth of about 70^{cm}. Promising territory as this would be, aquatic plants showed little disposition to invade it. An artificial excavation of any sort is

generally soon seized upon, and the fact that these marginal ditches remain devoid of vegetation, not being even bordered with the usual water margin plants, suggested to the writer that there must be some cause which prevents the growth of vegetation in that zone, and that this might be identical with the one which originally gave rise to the ditch. A rise of water, in conjunction with such a cause, might make a compound atoll.

Atkinson, in his *Lessons in botany*, makes additional suggestions in regard to the origin of the ditch, one of which is that it is caused by the shade of trees and shrubs growing on the solid land, and thus giving low vegetation around the border of a pool a poor opportunity. However, the northern edge of a pond is quite exposed to the sun during the hours of midday, yet the ditch exists there as markedly as anywhere else.

It was observed that formations of this character were found only in wooded districts, or on those recently cleared. Portions of the islands of the neighborhood are treeless, and in these localities the ponds were filling up from the margin in the well known manner.

Another fact was eventually noticed, namely, that the ditch varied in width, and that this variation bore a constant relation to the contour of the surrounding surface. The ditch is always widest where, from the arrangement of the surrounding slopes, the most material is washed in. That fact seemed to harmonize ill with ideas of erosion and deposit.

When the character of the material brought in was considered, however, an explanation of the different facts began to appear. The forest floor around is of humus, and covered with a close felt of roots, mosses, and mycelia. It does not take a long examination to convince one that ordinary erosive action of rain has literally ceased. Only fallen leaves and other organic matter is washed into the pond. Such is brought in, however, in quantities, and young plants which might start around the edge are constantly smothered. The bottom of the ditch may be seen always covered with quantities of dead leaves; and reaching into the water one can grasp great handfuls in all

stages of decay. New material, brought in with every shower, adds to the decaying mass, and produces a zone nearly destitute of growing plants, widest where the washings of the forest floor are most swept in.

Organic material, unmixed with sand or earth, in decaying forms solid strata very slowly. A considerable period must elapse before this zone is filled up. Even the detritus thus slowly formed may not remain at the margin, *for the island of vegetation is a floating one*, and the real bottom of the pool is more or less basin shaped. The islands are in fact floating mats, and are likely to afford only a very doubtful footing, but by felling a tree upon one somewhat smaller than the one shown, it was possible to reach the center and learn that in that case there are 2 or 3 meters of water in the center on which the floating island rests. The detritus resulting from decomposition of matter in the marginal ditch slides into the deeper parts of the pool, and thus the stage of the ditch is yet more prolonged. After the island becomes fixed, the ditch still fills very slowly. Even after the central area has been occupied by trees, it often may still be plainly traced.

SUMMARY.

In the filling-up of ponds, the activity of vegetation is in cases second to the physical factors of erosion and deposit. In open pools, anchored plants with floating leaves are often confined to a zone somewhat separated from the shore, their approach to the shore line being prevented by silt which is swept in, especially where the latter is shifted by wavelets. The physical factors in that zone thus exclude the organic. Plants of the shore line in such cases have running stems similar to those of sand binders, which enable them to escape death by burial.

The vegetation of the large open morainal pool, though undrained, may be purely hydrophilous. About the time of the formation of the floating mat the conditions appear to become xerophytic.

The marginal ditch which surrounds pond islands and atolls is in this region, at least, formed only in the woods, where a

dense felt of humus vegetation protects the ground from erosion. Fallen leaves and other organic materials swept from the forest floor into the edge of the pool tend to smother the vegetation which might grow there, and thus is produced a belt of open water, surrounding an island, or if the pond is larger a ring of vegetation.

TEMPLE COLLEGE,
Philadelphia.

A MORPHOLOGICAL STUDY OF THE FLOWER AND EMBRYO OF SPIRAEA.

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY. XXXVI.

JONATHAN E. WEBB.

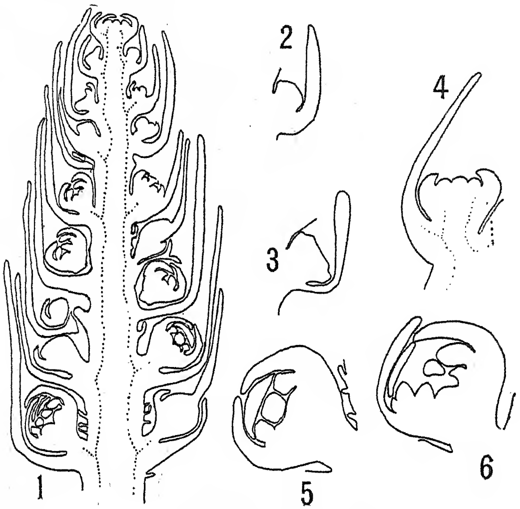
(WITH TWENTY-EIGHT FIGURES)

THE material used in preparing this paper was obtained largely from the Washington Park greenhouse, Chicago. Specimens of *Spiraea salicifolia* in various stages of development were secured from Grand crossing and East Chicago, Illinois, and from Marquette, Michigan. The species chosen for study was *Spiraea Japonica*, and this was supplemented by *S. astilboides planiflora* and *S. salicifolia*. Specimens were killed in chromacetic acid, Carnoy's mixture, and Flemming's mixture. All material was imbedded in paraffin, cut in serial sections with a microtome, and stained on the slide. Delafield's haematoxylin alone or in combination with erythrosin or iron alum was used chiefly, but cyanin and erythrosin, or the safranin, gentian-violet, orange G combination were used in certain cases. The Carnoy mixture was perhaps the most useful in every respect as a killing agent, and gave very satisfactory results.

ORGANOGENY OF THE FLOWER.

Spiraea affords an excellent opportunity for the study of the development of floral organs, as a longitudinal section of a spike gives many stages (*fig. 1*). At an early stage the rudiment of the flower appears as a protuberance in the axil of a bract (*fig. 2*). Five rather narrow ridges arise on the margin of this protuberance, and these ridges are the beginnings of the sepals, two of which are shown in section in *fig. 3*. Next there appears within this circle of ridges a whorl of papillae, the beginning of the inner five stamens, each opposite a sepal, and that this whorl does follow next is shown by the greater development of stamens

in that position (*fig. 10*). Immediately the third whorl of papillae appears, the individual members alternating with the second, and forming the second cycle of stamens, smaller and shorter than the first, and at a greater distance from the floral center (*fig. 9*). Contemporaneously with the second whorl of papillae, and while the first three whorls have as yet merely roughened the surface of the floral protuberance, two ridges, each strongly curved and with concave parts facing each other, arise at the center of the receptacle (*fig. 7*). These ridges fail to develop on the inner face except at their extremities, and the result is two carpels with cavities facing each other and nearly filled by the large development of the ridge-ends, which form the placentae. The transverse sections in *figs. 8* and *9* show this cavity, and how it is filled by the placentae before the development of the ovules. Although there are five carpels in *Spiraea salicifolia* and two in *S. Japonica*, leaving opportunity for variation from two to five, no evidence was found of the rudi-



Spiraea Japonica.

FIG. 1.—Longitudinal section of a young spike, showing floral development. × 23.

FIG. 2.—Floral papilla in the axil of a bract. × 54.

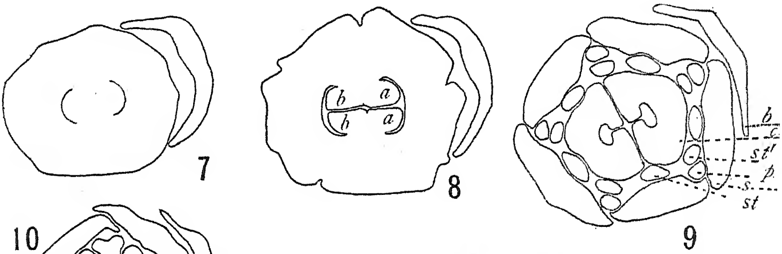
FIG. 3.—A later stage showing first appearance of sepals. × 54.

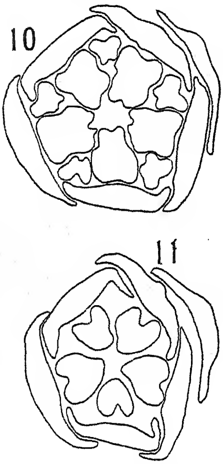
FIG. 4.—A stage showing sepals and stamens. × 54.

FIG. 5.—Longitudinal section passing through one side of the center of a flower, showing three stamens. × 54.

FIG. 6.—A longitudinal section of the same flower exactly through the center, showing that the capillary cavity is not yet closed above, and showing first appearance of petals. × 54.

ments of more than two carpels in the latter species. Once the form of the carpel is established, a rather uniform enlargement of all parts gives the necessary room for the many ovules. At the stage indicated in *fig. 9* the last cycle of floral parts, that of the corolla, has appeared, the petals alternating with the sepals, and lying just within their edges.





Spiraea Japonica.

FIG. 7.—Transverse section of flower at the base of the carpellary layer. × 54.

FIG. 8.—Section of same flower at point of maximum development of placenta; *aa*, *bb*, the ends of the two ridges enlarged, thickened, and curved. × 54.

FIG. 9.—Transverse section immediately above the plane of insertion of stamens and petals upon the receptacle; *b*, bract; *s*, sepals; *st*, stamen of the inner whorl; *c*, carpel; *st*, stamen of the outer whorl; *p*, petal. × 54.

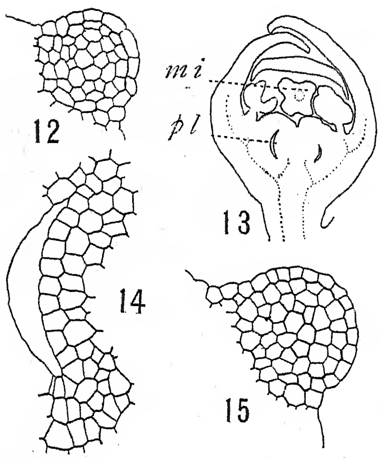
FIG 10.—Transverse section immediately above the top of the carpels, with ten stamens in section. × 54.

FIG. 11.—Transverse section near top of the largest stamens. × 54.

This development of floral parts in Spiraea shows that the order is as follows: sepals, inner stamens, carpels and outer stamens, petals (*figs. 9, 10*).

The development of microsporangia and megasporangia is rapid, and maturity is reached in a week or two; the megasporangia, however, attain their full development later than the microsporangia. At an early stage the anthers have, to some extent, become rounded and enlarged, while the carpellary cavity even has not yet been closed over above (*fig. 6*). Again, when the four microsporangia of an anther are well marked, the

placentae are still wholly undifferentiated (*figs. 14* and *15*). The ovules are yet without integuments at a time when the microsporangia have a well marked tapetum and the sporogenous tissue has neared the spore mother cell stage (*figs. 17* and *18*). The initiation of the integuments on the ovules occurs at the time of the tetrad stage of the microsporangia, or while the pollen grains are separating and becoming round, and before the dominant megaspore has been determined. At this stage the microsporangium is inactive until the pollen is shed.



Spiraea Japonica.

FIG. 12.—Transverse section of a young stamen, showing homogeneous character of the archesporial mass. × 54.

FIG. 13.—Section through center of flower after carpellary cavity is complete, showing placenta; *mi*, microsporangium; *pl*, placenta. × 54.

FIG. 14.—Longitudinal section through placenta of same flower. × 350.

FIG. 15.—Microsporangium of same flower. × 350.

THE MICROSPORANGIUM.

In the development of the flower the second whorl of papillae to arise on the receptacle is that of the stamens. These papillae early become stalked below, enlarged and rounded above. In Typha[1] this enlargement does not occur until much later. While the placenta is still composed of large, undifferentiated cells, and before the appearance of the ovules, the microsporangia have attained their characteristic quadrilocular form, and the epidermal layer is separated from the hypodermal by heavier walls (*figs. 12* and *15*). This is the first differentiation of any kind in the cells of the microsporangium, characterized by size of cells, thickness of cell walls, or depth of stain; and no archesporial cell or plate of archesporial cells appears at any stage in a close

[1] SHAFFNER, BOT. GAZ. 24: 94–95. 1897.

series of preparations. Shortly thereafter the peripheral layer of the hypodermal mass may be distinguished by its lighter color and incipient periclinal division, which results in two narrow layers of cells derived from the archesporial tissue, as shown in *fig. 18*, the latter showing this division of the hypodermal layer partially completed, and with no precise differentiation of the cells of the included sporogenous mass. For although the separation of tapetum from sporogenous tissue has already been made, there is nothing which shows this conclusively but the peripheral position of a layer of cells, and the number of cells in a cross section equal, as it is, to the number in later stages. On the other hand, the cells of the tapetal cylinder clearly show by their shape and intimate association with those of the central sporogenous mass that the origin of tapetal and sporogenous cells is one. The chance of position alone keeps the former from being sporogenous cells. Their position, however, compels them to act as purveyors of nutrition to the other sporogenous cells, a task for which they are eminently fitted by their kinship. Yet by the very accomplishment of this task they are so changed as to be incapable of acting, like their sisters, as spore mother-cells.

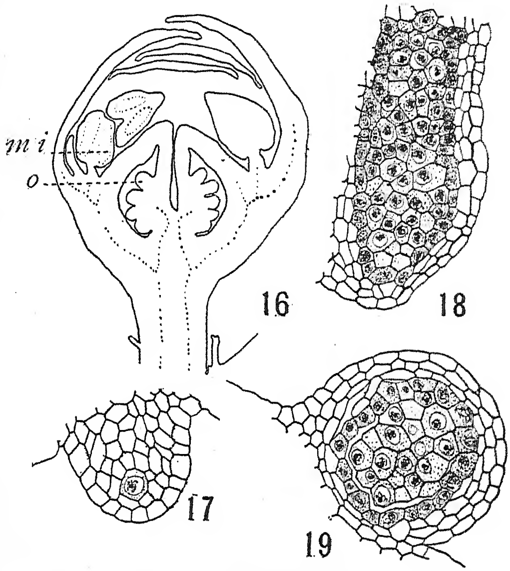


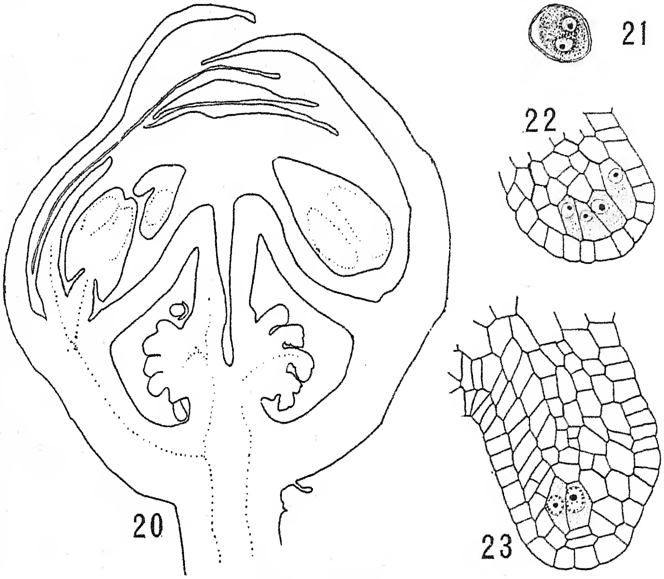
FIG. 16.—*Spiraea astilboides planiflora.* Longitudinal section of a flower, showing all parts, including petals and ovules; *mi*, microsporangium; *o*, ovule. × 54.

FIG. 17.—Ovule of same section, with tapetum cut off. × 350.

FIG. 18.—Microsporangium of same section, with division to form the endothecium. × 350.

FIG. 19.—*Spiraea salicifolia.* Transverse section through microsporangium with well developed tapetum. × 350.

Although such an explanation of the tapetal layer is impossible for many microsporangia, as in Cnicus,[2] yet its possibility has been suggested by Coulter in Ranunculus.[3] By gradual changes the tapetal layer is clearly differentiated from the spore mother-cells until it stains more deeply, has a more homogeneous appearance, and acquires a tendency to separate from the spore



Spiraea Japonica.

FIG. 20.—Longitudinal section through flower with all parts represented and showing beginning of the integuments. × 54.

FIG. 21.—Pollen grain with two nuclei at time of shedding. × 550.

FIG. 22.—Longitudinal section of young ovule with four archesporial cells. × 550.

FIG. 23.—Longitudinal section with the first layer of tapetal cells and two potential megaspore mother-cells. × 550.

mother-cells, although several cells in the layer might from their appearance be either tapetal or sporogenous (*fig. 19*). This stage is followed by the thickening of the tapetum, until it becomes a layer rich in food material, homogeneous throughout,

[2] COULTER, Contributions to the life history of Ranunculus. BOT. GAZ. **25**: 73–88. *pls. 4-7.* 1898.

[3] COULTER, *ibid.*

surrounding the spore mother-cells in a late synapsis stage, and itself surrounded by two layers of narrow, lightly staining wall cells. This condition persists for some time as regards the tapetum, until one of the wall layers is absorbed and the other has become very much thickened at the stage of the division of the spore mother-cells into tetrads; then the microspores round up, and at the time of shedding they have disorganized the tapetal cells and have absorbed their contents. Of the two layers between tapetum and epidermis, mentioned above, the inner has now disappeared, having been absorbed by the tapetum for the benefit of the sporogenous tissue. The outer or endothecium has become a thick layer by reason of the enlargement of its cells in which the nuclei are not conspicuous, but the walls have characteristic thickenings. At this stage there are two nuclei in the pollen grain (*fig. 21*).

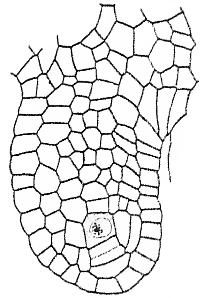


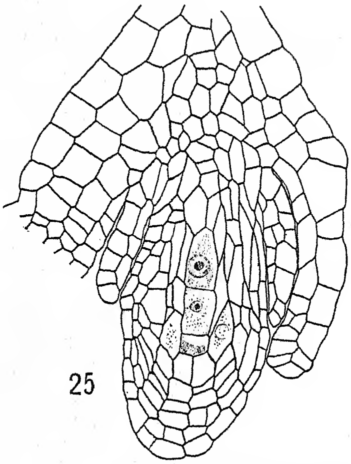
FIG. 24.—*Spiraea Japonica.*—Longitudinal section through an ovule showing a row of three tapetal cells and one large megaspore mother-cell. × 550.

THE MEGASPORANGIUM.

The comparative rate of development of stamens and ovules has already been stated. Long before the appearance of the integuments, and while the ovules are but slightly developed on the placenta, several hypodermal cells at the tip of the ovule become enlarged, and their nuclei differ in size and arrangement of contents from those of neighboring cells (*fig. 22*). This mass of archesporial cells in the ovule of Spiraea is comparable to that found in *Rosa livida* by Strasburger.[4] Ensuing periclinal division results in forming two masses, the hypodermal being the tapetal mass, and the other the sporogenous mass. Successive divisions of the cells of the tapetal layer by periclinal walls result in adding much to the length of the ovule and the distance from the sporogenous tissue to the epidermis. Periclinal divisions in the epidermis itself also add to the length of the ovule

[4] STRASBURGER, Angiospermen und Gymnospermen. 1879.

(*fig. 25*). This method of division causes a radial appearance in a longitudinal section from the region of the embryo sac to the micropyle, which has been figured for *Rosa livida* by Strasburger,[5] and occurs in other members of the rose family, such as *Pirus Malus*. There are variations in the number of megaspore mother-cells which enlarge for division. This number is usually one, but often two or three begin to divide, and then



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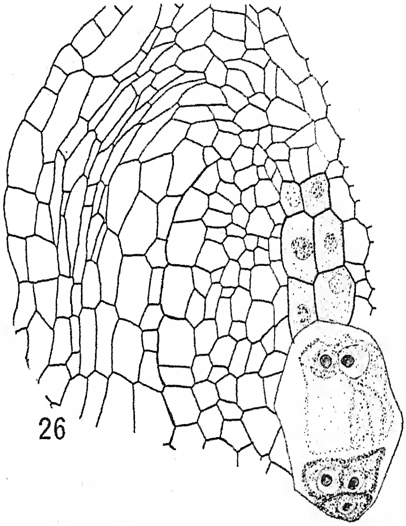

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FIG. 25.—*Spiraea Japonica*. Longitudinal section of an ovule with integuments, large tapetal development, three large potential megaspores, and several megaspores breaking down. × 550.

FIG. 26.—*Spiraea Japonica*. Longitudinal section of mature embryo sac normally developed, showing thick nutritive cells in the chalazal region. × 550.

all but one break down. The successful megaspore is the one nearest the chalazal end of the sac, and it may be one of two, three, or four (*fig. 25*). It is very seldom that a megaspore nearer the micropyle shows any signs of reaching the fertilization period, although this doubtless happens in some cases, as is indicated by *fig. 27*, in which the megaspore nearer the micropyle has begun to develop, and is evidently the one which will reach maturity.

[5] STRASBURGER, *ibid.*

The embryo sac follows the normal order of development, and at an early stage there occurs a thickening of cells in the chalazal region adjacent to the megaspore (*fig. 26*), and this spreads until it includes the whole of the layer of integument adjacent to the nucellus (*fig. 27*). At this stage the contents of the embryo sac are rich in food material, especially starch.

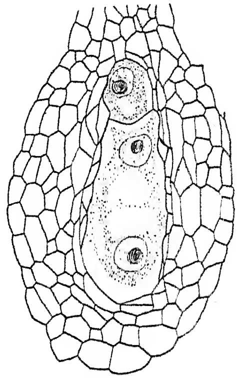


FIG. 27.—*Spiraea Japonica*. Megasporangium in which two megaspores of the same row, resulting from one division of the mega-spore mother-cell, have begun to develop, with the micropylar spore ahead. × 550.

THE EMBRYO.

In reference to the embryo, it need only be said that the development is regular and normal, and that the suspensor, unlike that of the legumes, but in accordance with typical illustrations of suspensors, consists of but a single row of cells of no extraordinary size (*fig. 28*). Their purpose is evidently that of directing the food supply derived from the embryo sac, and supplied by the endosperm, which surrounds or clings to the embryo at this stage, to the embryonic root region.

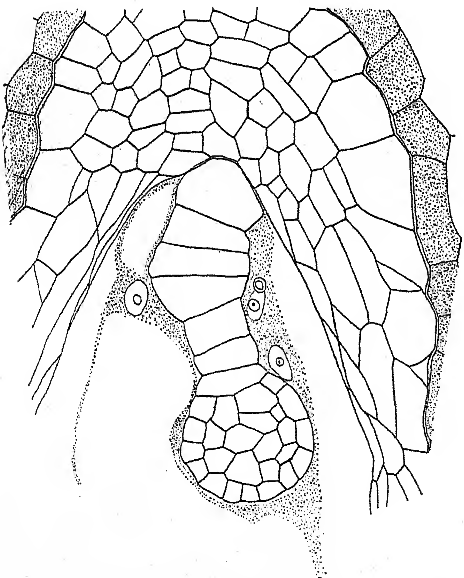


FIG. 28.—*Spiraea Japonica*. Longitudinal section through a young embryo with simple suspensor. × 550.

CONCLUSIONS.

1. The order of floral development is as follows: sepals, inner stamens, carpels, outer stamens, petals.

2. The microsporangia reach maturity before the megasporangia.

3. No archesporial cell or plate of archesporial cells is differentiated in the microsporangium.

4. The tapetum is cut off from the outside of the sporogenous mass.

5. Several archesporial cells are differentiated in the megasporangium. These cut off tapetal cells, by the divisions of which the megaspore mother-cells become deep-seated.

6. The megaspore mother-cell which is centrally located develops, and the megaspore near the chalazal end of the ovule is usually the successful one.

7. Enlargement of certain cells with thicker walls and denser staining contents takes place in the chalazal region of the nucellus as nutrition is supplied through these cells for the development of the embryo sac.

8. The development of the embryo is normal, and the suspensor is simple.

The work in preparation for this paper was done at the University of Chicago, under the direction of Professor John M. Coulter and Dr. Charles J. Chamberlain.

HULL BOTANICAL LABORATORY.

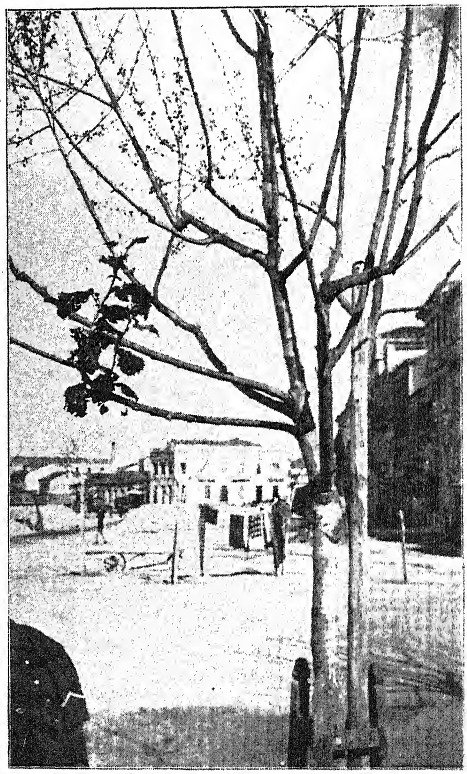
BRIEFER ARTICLES.

NOTES OF TRAVEL. IX.

A PRECOCIOUS POPLAR BRANCH.

(WITH ONE FIGURE)

In the plaza at Patras, the principal commercial port of Greece, are a number of poplar trees that have been recently planted out for shade. When I was there in March 1901, these trees were just beginning to unfold their leaves, and my attention was attracted by a remarkably precocious branch on one of them, which was so far ahead in its development that it stood out as prominently against the sky as a clump of mistletoe does on a Kentucky oak in winter. The leaves on this branch were fully developed, in fact seemed to me more luxuriant than usual, and the case was so striking that I took a kodak picture of the tree. On examining the branch somewhat closely, I found that it arose from a wound which seemed to have been produced by some wagon in its passage along the street. The wound had healed, and this most pre-



Poplar tree in Patras, Greece, with precocious branch.

cocious branch originated near the callus which had formed over it.

The importance of this curious case of precocity is its possible bearing upon the production of earlier developing varieties of shade or fruit trees. The literature may be full of references to the matter, but so far as I am aware no one has made the attempt to originate an early leafing variety of ornamental trees by wounding the branches and looking for precocious shoots from the wounds, from which to propagate by buds or cuttings. It is possible that cuttings taken from a branch originating in this way may prove no earlier than the mother plant, but there is also a possibility that the wound has led to the production of an adventive bud which has varied in the direction of precocity.

I am confident that in such cultures as the hop, where the plant has been propagated asexually for centuries, bud variation plays an important part in the formation of new strains or races; and new Citrus varieties are suspected to have originated in this way. Just how great this variation is, and how often it can be utilized, remains a question for research. The case here described seemed so striking that I thought it worthy of a short note and a photograph. There was no sign of the branch having been budded with a different variety, and, unfortunately, I do not know the species of the tree. In fact, the interest of the case only appeared to me after I was many miles away from Patras.

It would be interesting to know whether the same branch developed a second year much earlier than the other branches of the tree, *i. e.*, whether this precocity was the result of a direct but transitory stimulus of the wound, or a constant character of the bud produced near the wound.—DAVID G. FAIRCHILD, *Department of Agriculture, Washington, D. C.*

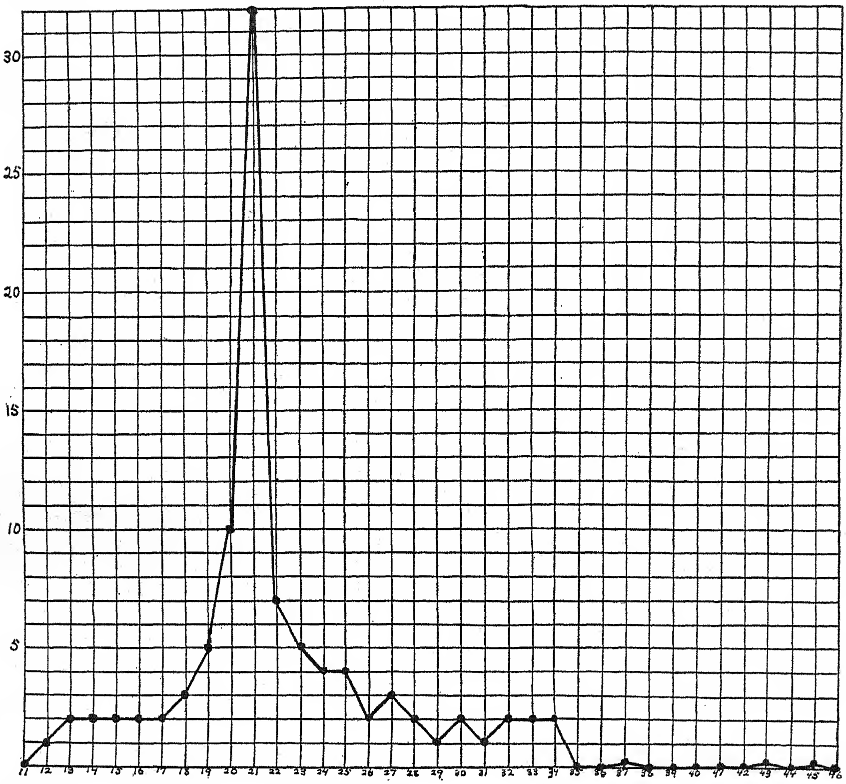
NUMERICAL VARIATION OF THE RAY FLOWERS OF COMPOSITÆ.[1]

(WITH ONE FIGURE)

THE following observations constitute a preliminary report upon the variation, both numerical and morphological, exhibited by the flowers

[1] Contributions from the Laboratory for Plant Physiology and Pathology of the Alabama Polytechnic Institute. I.

and inflorescence of the Compositæ, a subject which I have had under investigation for several years. The present paper treats only of the numerical variation found in the ray-flowers of *Helianthus annuus*. These particular studies were completed while I was connected with



Curve of variation.

the Oklahoma Agricultural and Mechanical College. I take pleasure in acknowledging my obligations to Mr. A. C. Lewis of that institution for assistance.

If we may judge from some recent utterances of botanists and zoologists, is is evident that the mathematical and statistical study of variation is destined to occupy a prominent part in the development of biological research. Dr. Robinson, in his address as retiring President of the Botanical Society of America, said, "that among the subjects which

seem to invite immediate attention the most important are: (1) the determination of the modes and degrees of variation, an investigation which alone can yield data for a more critical discrimination of plant categories."[2] Equally forceful words were spoken by Dr. Davenport in his address as retiring vice-president of Section F of the A. A. A. S. at its Denver meeting. He said[3] "the science of variation is therefore one of those that we may hope to see established in this century. I feel convinced that statistical studies are first of all necessary to lay the foundations of the science." The recent establishment of the periodical "Biometrika" will do much to increase the general interest in this department of biological investigation.

The specimens of *Helianthus annuus* selected for this study were growing on vacant lots in Stillwater, Oklahoma, forming there the typical sunflower waste-formation so characteristic of that region. Determinations of the number of ray flowers were made on a total of 1103 heads selected at random over the various vacant lots. The following tabulation and curve of variation show the results thus secured.

Class	Individuals in the class	Percentage of individuals in the class	Percentage of individuals in this or a higher class	Class	Individuals in the class	Percentage of individuals in the class	Percentage of individuals in this or a higher class
12	10	0.90	100	29	16	1.45	11.78
13	22	1.99	99.09	30	26	2.35	10.33
14	23	2.08	97.09	31	15	1.35	7.97
15	25	2.26	95.01	32	25	2.26	6.61
16	22	1.99	92.74	33	20	1.81	4.35
17	26	2.35	90.75	34	25	2.26	2.53
18	40	3.62	88.39	35	0	0	0.27
19	50	4.53	84.76	36	0	0	0.27
20	112	10.15	80.23	37	1	0.09	0.27
21	352	31.91	70.08	38	0	0	0.18
22	80	7.25	38.16	39	0	0	0.18
23	50	4.53	30.91	40	0	0	0.18
24	40	3.62	26.38	41	0	0	0.18
25	42	3.80	22.75	42	0	0	0.18
26	25	2.26	18.94	43	1	0.09	0.18
27	36	3.26	16.68	44	0	0	0.09
28	18	1.63	13.41	45	1	0.09	0.09

From the above tabulation and frequency curve the following facts are secured. The class having 21 ray flowers includes over 31 per cent. of all the individuals. Slightly over 10 per cent. of all the individuals

[2] ROBINSON, B. L., Problems and possibilities of systematic botany. Science 14:474. 1901.

[3] DAVENPORT, C. B., Zoology of the twentieth century. Science 14:319. 1901.

are segregated in classes 30 to 34 inclusive, while only 3 individuals were found having more than 34 ray flowers.

The curve shows a positive skewness of 1.1, but at present it cannot be stated whether this skewness is toward or away from the ancestral condition of the species. Seeds collected from heads having given numbers of ray flowers have been secured for breeding purposes and the study of the plants thus secured may enable us to properly interpret the skewness here observed.—E. MEAD WILCOX, *Alabama Polytechnic Institute, Auburn.*

CURRENT LITERATURE.

BOOK REVIEWS.

Plant pathology from a new standpoint.

A RECENT work by Professor H. Marshall Ward[1] places the subject of plant diseases in a new light that must prove very helpful and suggestive to students, as well as to cultivators who are able to read the work understandingly. If every one interested in the cultivation of plants were fairly well informed regarding vegetable physiology and pathology, the work could be said to be a popular treatise, for it is written from the standpoint of the plant and the plant grower, and not, as is usual, from that of the fungus or other disease agent and the mycologist. Moreover, technical terms are employed only where English equivalents are not available, or where obscurity and prolixity are to be avoided.

The work is not a manual of vegetable therapeutics, as may be judged from the fact that only ten pages are devoted to remedies; and it is not a mycological treatise, as it does not describe fungi, but when mentioning them assumes that the reader already knows them. However, it treats of the general nature of disease in plants in a broad and philosophical way. To give a deeper and truer insight into the subject, an introductory part of eighty-five pages reviews the fundamental features of normal physiology and power of adaptation, based upon the very latest researches. It is excellent reading. In this part strong blows are dealt against the persistent ignorance and misconception that falsely exalt chemistry to the first place among the sciences which aid the cultivator, that misconstrue the nature of plant food, that consider the soil an inert substance, and that fix the attention of the cultivator upon the weather and the environment, rather than upon the plant itself. In America these and kindred errors are rapidly being corrected through the influence of the Experiment Stations and Agricultural Colleges, and we have already discarded the use of some terms based upon these errors, notably the misleading word "carbon-assimilation," which the author apparently feels it his duty to cling to for the present.

The body of the book deals with such topics as health and disease, life and death, causes, nature, and symptoms of disease, the factors of an epidemic, relation of variation to disease, grafts, wounds, excrescences, exudations, and monstrosities. These and similar topics are treated with a directness

[1] WARD, H. MARSHALL, Disease in plants. 12mo, pp. xiv + 309. London: The Macmillan Company, 1901.

and depth that can be very imperfectly suggested in a brief review. No class of readers will get so much profit and satisfaction from the work as those who desire to know the latest word that science has to offer in explanation of the causes and principles underlying the phenomena of plant activity in both health and disease, and who desire the information presented in a luminous, concise manner, and so far as possible, in untechnical language.

When the point of view of the author becomes the prevalent point of view both of the public and the investigator, great advantage will accrue to all who deal with plants, and this work should be an important factor in hastening the time.—J. C. ARTHUR.

The Cyclopedia of American horticulture.

THE fourth and last volume of Bailey's *Cyclopedia of American horticulture* has just appeared.[2] The scope and quality of this great work have been spoken of in reviews of the preceding volumes.[3] The editor hopes that this Cyclopedia will never be revised, "for it is the purpose of the book to make a record of North American horticulture as it exists at the opening of the twentieth century." It is expected that subsequent progress will be recorded in a series of supplements with cumulative indexes, the manuscript for the first two of which is already prepared. Numerous important genera are presented in the usual way, notable among which are *Rosa*, *Rubus*, *Salix*, *Saxifraga*, *Sedum*, *Selaginella*, *Spiraea*, *Tulipa*, *Vitis*. These and other genera are all treated in the usual way, the synoptical keys of the cultural species being followed by descriptions of treatment, regions of cultivation, etc. The treatment of roses is especially noteworthy, the editor venturing the opinion that this subject will probably be consulted oftener than any other in the Cyclopedia. In order to make it worthy of such a place the treatment is particularly full. After the usual scientific synopsis, including fifty species, the horticultural classification is presented, followed by a discussion of the treatment of roses, their adaptation to different regions and all other points of view that might be of interest to those cultivating roses. Perhaps the most notable articles dealing with fruits are those upon the strawberry and tomato.

Aside from such papers there are noteworthy articles upon *Railroad gardening*, *Rock gardens*, *Seedage*, *Spraying*, and *Storage*. By the name *Seedage* the editor refers to the propagation of plants by seeds and spores, and after the general treatment there is a section upon *Seed breeding* by W. W. Tracy, and one upon *Seed testing* by G. H. Hicks. Under the general title

[2] BAILEY, L. H., Cyclopedia of American horticulture, etc. Vol. IV. R–Z. 4to, pp. xxx + 1487–2016, *figs. 2060–2800*, *pls. 32–50*. New York: The Macmillan Company. 1902. $5.

[3] BOT. GAZ. **29**:282; **30**:277; **31**:436.

Storage, presented by the editor, there is an account of *Cold storage* by L. C. Corbet, and of *Refrigerator cars* by J. H. Hale.

Aside from the taxonomic presentation of many genera, perhaps the most interesting articles to botanists are *Teratology*, presented by C. R. Barnes; *Trees*, presented in all their aspects by various writers; and *Winter protection*, described and illustrated by W. C. Egan and B. M. Watson.

Professor Bailey is to be congratulated upon the completion of this work, especially upon the peculiar features it possesses in comparison with the ordinary cyclopedias dealing with horticultural material. Its chief features, as they stand out in the mind of the editor, are that it represents a living horticulture, rather than a compilation of odds and ends selected from other encyclopedias; that it contains synoptical keys that enable the reader to name the species; that the leading articles are signed and represent the contributions of more than 450 persons; and that throughout the whole presentation one detects no rigid conception of plant, forms, but feels the drift of an evolutionary motive. That such a work should have been begun, so far as actual writing is concerned, in January 1899, and the last proof read December 31, 1901, speaks well for the organizing power and the capacity for work of its editor and his staff. The statistics show that the total number of entries is 4357; the number of genera described is 2255; the number of species fully described is 8793, of which 2419 are native to North America north of Mexico.—J. M. C.

Physiology in the laboratory.

To STUDY the plant in action is to become acquainted with the most interesting phase of the science of botany. It is a part of the subject that appeals especially to the young student. But to make intelligent progress, to look into the more recondite processes without elaborate apparatus, and to proceed without undue loss of time and check to enthusiasm requires a good guidebook. Even under an excellent instructor a handbook is advantageous. A work that meets the requirements for a laboratory manual of physiology for the beginner has recently been issued from the press of Longmans, Green & Co., prepared by Dr. Daniel T. MacDougal,[4] director of the laboratories of the New York Botanical Garden.

The work is perspicuous, concise, up to date, and requires only simple apparatus, easily obtained by most colleges and high schools, and in part no apparatus at all. The whole ground of physiology is covered: growth and growth movements, reproduction and germination, movements of gases and liquids, nutrition of green plants, parasites and saprophytes, respiration, digestion, stimulation, and correlation.

The text is more than a set of directions for performing experiments, for

[4] MACDOUGAL, DANIEL TREMBLY, Elementary plant physiology. New York: Longmans, Green & Co. 1902. 12mo, pp. xi+138, with 108 text cuts.

it gives a readable account of many topics, and incidentally furnishes much information upon the general subject of physiology. The cuts are especially serviceable in showing how the student is to proceed. In short, the work comes as near as possible to the perfect manual, which tells enough to be helpful and attractive, and yet leaves the student to ascertain the actual facts for the most part by his own observations upon the living plant or in introductory demonstrations.

The work is all the more satisfactory for being the outgrowth of two preliminary works, the first published in 1894 and the second in 1895, both now out of print.—J. C. ARTHUR.

MINOR NOTICES.

THE SECOND FASCICLE of Ohio fungi, distributed by Professor W. A. Kellerman, of Columbus, O., has been issued, and is larger than the preceding one. It contains twenty-six numbers, of which seven belong to the genus Puccinia, five to Uromyces, three to Ustilago, two each to Gymnoconia and Gymnosporangium, and one each to Aecidium, Gloeosporium, Melampsora, Piggotia, Polystictus, Stereum, and Urocystis. The excellent preparation and fullness of material is maintained. The first fascicle was described in the March number of this journal (p. 239). Although these fascicles are intended for distribution to working mycologists, the author has consented to sell a very limited number at one dollar each.—J. C. ARTHUR.

THE SECOND EDITION[5] of Frost's *Laboratory guide in elementary bacteriology* (8vo) is much more convenient in form than the first (4to) edition.[6] It combines the features of a laboratory outline and of a notebook, blank pages and diagrams being inserted for records of the student's observations. The author recognizes the desirability of uniformity in cultural methods, and gives in addition to the ordinary laboratory methods of preparation of culture media those recommended by the committee on methods of the American Public Health Association. Part I is devoted to general bacteriology, with introductory chapters on morphology, physiology, and taxonomy. In the latter a number of valuable descriptive adjectives, similar to those suggested by Chester, are introduced. Part II deals with medical bacteriology, with appended chapters on animal inoculation and the examination of pathological tissues and fluids. In connection with each exercise are references for the student, both to the principal texts and to original articles on the subject under consideration. The guide is admirably planned and will form a welcome aid in the teaching of bacteriology.—E. E. IRONS.

[5] FROST, WILLIAM DODGE, A laboratory guide in elementary bacteriology. Second revised edition, pp. x + 355. Madison, Wis.: Published by the author. 1902.

[6] See review in BOT. GAZ. 31 : 439. 1901.

DR. HOLLRUNG[7] has just published his third annual report on plant pathology. This report does not differ in its essential features from the two that have preceded it. The work covers the ground that has been done along the various lines of plant pathology in different countries during the year 1900, and is divided into a general and a special part. The general part brings together (1) the progress made in the organization of plant protection, (2) the laws and ordinances relating to the protection of plants, and (3) the relation of plant diseases to the weather, methods of the dissemination of diseases, the influence of diseased plants upon man and other animals, etc. The special part of the report embraces the work done in 1900 in determining the causes of plant diseases and the means of combating them. The causes of plant diseases are considered, first from the standpoint of injuries from various sources without reference to the host plant, and second the causes of injury to different host plants. Under the former subdivision mention is made of destructive animals, such as field mice and marmots, and the means employed in destroying them; of injurious insects, their development and their control; and of weeds and the means used for their destruction. Under the second subdivision the host plants considered are grains, fodder, sugar beets, white potatoes, sweet potatoes, pod fruits, truck crops, garden products, seed and stone fruits, berries, grapes, timber, tropical plants, and ornamentals. The natural methods of combating plant diseases embrace the work done on birds, insects, fungi, and bacteria injurious to plants; while the artificial methods cover the advances made in the construction of spraying machines, as well as in the preparation of insecticides and fungicides, including powders, liquids, and gases. The report covers about 176 pages, the major portion being devoted to the special part. This is followed by about 90 pages of references to bulletins and papers, subdivided in accordance with the general plan of the work and arranged alphabetically with respect to the names of the authors mentioned under each subdivision. The work closes with a complete index, giving the names of the authors, host plants, insects, fungi, etc., thus making a very satisfactory work of reference. Dr. Hollrung seems to have been very desirous of citing everything published along all lines treated in this report, and considering the great diversity of subjects, together with the wide geographical area covered, it is surprising, and at the same time a matter for congratulation, that the work has been so carefully and so thoroughly performed in every way. In bringing out this report in such a satisfactory manner, Dr. Hollrung has rendered valuable service to all workers along the various lines of plant diseases, and it is to be hoped that he will receive sufficient encouragement to enable him to continue the good work.

[7] HOLLRUNG, DR. M., Jahresberichte ueber die Neuerungen und Leistungen auf dem Gebiete des Pflanzenschutzes. Das Jahr 1900. Pp. viii + 291. Berlin: Paul Parey. 1902. *M* 10.

He closes his preface to this third report with an earnest request that all parties actively engaged in any work relating to plant pathology would forward him separates of their published articles.—C. O. TOWNSEND.

NOTES FOR STUDENTS.

PROTOPLASMIC CONNECTIONS in a large number of plants belonging to all groups from algae to flowering plants have been studied recently by Keinitz-Gerloff.[8] Previous investigations have already made it seem probable that protoplasmic connections are universally present in the spermatophytes; the present work shows that the connections are as uniformly present in the lower groups, the filamentous algae perhaps being an exception. In such algae, however, each cell is so independent in nutrition and reproduction that the absence of connections need not occasion surprise. The suggestion is made that the connections may not be derived wholly from the *Hautschicht*, but that they may have a core of trophoplasm surrounded by *Hautschicht*. The theory that the connections conduct stimuli and materials is supported, but the reviewer believes that the whole subject needs further investigation.—CHARLES J. CHAMBERLAIN.

THE PHYSIOLOGY of adjustment to poisons dissolved in the medium has been made the subject of a contribution by Pulst.[9] He worked with the Mucor, Aspergillus, Botrytis, and Penicillium. The effect of a number of kations was determined, among them Cu, Zn, Hg, Ni, Co, Cd, Pb, etc. The anion SO_4 was usually used, but some others (*e. g.*, $C_4H_4O_6$, CN, NO_3, Cl, etc.) also appear in the tables. Penicillium withstands a much higher concentration of these substances than do the other three moulds. The effect of a salt upon the plant appears to depend in great measure upon the electrical charge of the kation, also in part upon the action of undissociated molecules. As was known before, a gradual increase in concentration brings about an accommodation to much stronger solutions than could be withstood if the change were made suddenly. Copper ions appear to be unable to penetrate the protoplast of Penicillium, though the other protoplasts studied are readily permeable to them.—B. E. LIVINGSTON.

ACCORDING TO SHIBATA,[10] the fertilization of the egg and polar nuclei of *Monotropa uniflora* is practically the same as has been observed in all the forms in which double fertilization is known. The sperms are elongated when they enter the embryo sac, and become more nearly spherical as fusion progresses.

[8] Neue Studien über Plasmodesmen. Ber. Deutsch. Bot. Gesell. **20**: 93–117. *pl. 4.* 1902.

[9] PULST, C., Die Widerstandsfähigkeit einiger Schimmelpilze gegen Metallgifte. Jahrb. Wiss. Bot. **37**: 205–263. 1902.

[10] SHIBATA, K., Die Doppelbefruchtung bei *Monotropa uniflora* L. Flora **90**: 61–66. 1902.

The second male cell comes in contact with the upper polar nucleus, while the lower polar nucleus comes in contact with the male cell and upper polar nucleus and the three fuse simultaneously. The endosperm nucleus divides before the oospore shows signs of division. Only in Naias, as reported by Guignard, does the oospore divide first, but even here, when division of the endosperm begins, it proceeds with much greater rapidity than in the embryo. The two deeply staining bodies reported by the reviewer in the end of the pollen tubes of Silphium and Erigeron were observed and figured in Monotropa, but their origin was not determined. The article is illustrated with ten excellent figures. — W. J. G. LAND.

HAUPT[11] adds somewhat to our knowledge of gland action by a recent paper from the Leipzig laboratory. Working with extrafloral nectaries, he finds that the secretion of sugar begins at a certain age of the nectary and with relatively high atmospheric humidity, *i. e.*, with checked transpiration. After it is started, a rise in humidity increases the amount of water excretion, but that of sugar remains constant. Usually when secretion is stopped, the already secreted sugar fails to be resorbed, but in some cases resorption occurs. In Vicia and certain Euphorbiaceae the red and yellow rays of the sun's spectrum are necessary for the secretion of sugar, and the secretion is resorbed in darkness, or in blue and violet light. Plants deprived of CO_2 exhibit the light reaction even after many days; thus the response is not connected with the photosynthetic process. There exists in all plants experimented upon a minimum temperature for the beginning of secretion, but after the process has begun it goes on slowly even somewhat below this minimum.— B. E. LIVINGSTON.

THE EMBRYOLOGY of the Araliaceae has just been described at some length by Ducamp.[12] He finds, as a rule, only one archesporial cell in the nucellus of the ovule. This cell gives rise to a tapetal cell and the megaspore mother cell. The mother cell may develop directly into the embryo sac, or may first give rise to an axial row of three or four megaspores, the lowest of which usually germinates, although one of the middle cells occasionally develops at the expense of those above and below. In *Fatsia Japonica* a case is figured in which the middle cell of an axial row of three had divided longitudinally. In another case, after the mother cell had divided transversely, both daughter cells had divided longitudinally. A case in which two mother cells in a single nucellus had divided in this manner gives the nucellus a very sporangium-like character, and in the opinion of the writer strengthens the

[11] HAUPT, HUGO, Zur Secretionsmechanik der extrafloralen Nektarien. Flora 90: 1–41. 1902.

[12] DUCAMP, L., Recherches sur l'embryogénie des Araliacees. Ann. Sci. Nat. Bot. VIII. 15: 311–402. *pls. 6–13.* 1902.

theory that the nucellus is the homologue of the sporangium of the cryptogams. The statement is made that the division of the nucellus of the mother cell sometimes takes place without the formation of cell walls, but the figures are very small and may bear another interpretation. Double fertilization was looked for, but nothing definite was found. The development of the embryo and the appearance of tissue systems are described in detail.—CHARLES J. CHAMBERLAIN.

ITEMS OF TAXONOMIC INTEREST are as follows: C. V. PIPER (Bull. Torr. Bot. Club **29**: 221–226. 1902), in his sixth paper entitled "New and noteworthy northwestern plants," describes new species of Antennaria (2), Madia, Synthyris, Astragalus, and Philadelphus.—J. C. ARTHUR (*idem* 227–231), in his second paper entitled "New species of Uredineae," describes new species of Uromyces (2), Puccinia (4), and Uredo (2).— P. A. RYDBERG *idem* 232–246), in his eighth paper entitled "Studies on the Rocky mountain flora," describes new species of Stanleya (2), Thelypodium (2), Lepidium (2), Roripa (3), Lesquerella, Physaria, Cardamine, Sophia (2), Draba (7), Geranium (2), Oxalis, and Lupinus (4).—ALICE EASTWOOD (Proc. Calif. Acad. Sci. III. Bot. **2**: 241–252. *pls. 23–24.* 1902) has published nine new species of Ribes from the Pacific coast, and also a key to the 57 species of that region.—C. D. BEADLE (Biltmore Bot. Studies **1**: 51–137. 1902) has published 104 new species of Crataegus from the southeastern states.— F. E. BOYNTON (*idem* 138–142) has published new southern species of Amorpha (2) and Coreopsis (2).—T. G. HARBISON (*idem* 158) has published a new Trillium from Alabama.—C. D. BEADLE (*idem* 159–163) has published new southern species of Philadelphus (3) and Prunus (2).— Dr. WEBER (Bull. Soc. Nat. d'Acclim. de France, May 1902), in his second paper entitled "Études sur les Opuntia," has discussed *O. leucotricha*, the "duraznillo" of the Mexicans, and also the six other species of the section CRINIFERA, one of them (*O. Gosseliniana*) being new.— E. L. GREENE (Ottawa Nat. **16**: 35–39. 1902) has described new northwestern species of Actaea (3), Delphinium, Cerastium (3), Carduus, Erigeron (2), Pentstemon, and Lappula.—J. M. C.

PROFESSOR F. O. BOWER[13] has called attention to the imperfect sporangia of pteridophytes, notably those at the base and apex of the strobili of lycopods, in which group 94 species were examined. In certain forms there is no line of demarcation between the strobilus and the vegetative part of the plant, any leaf being a potential sporophyll. The other extreme is to be found where the strobilus is made up of sporophylls whose form and arrangement differ from the foliage leaves. All degrees of transitional stages exist. In all species quite constantly abortive or imperfect sporangia were found at the base, apex, or in sterile zones of the strobilus. The author discusses these

[13] Imperfect sporangia in certain pteridophytes. Are they vestigial? Annals of Botany **15**: 225–267. 1901.

incompletely developed sporangia "in order that these facts may have their true weight in the general discussion of vegetative and fertile regions of the primitive leafy sporophyte." It is possible to look upon an imperfectly developed part as either upon the up-grade (nascent) or on the down-grade (evanescent) of development. These terms "nascent" and "evanescent" may be applied to either the ontogeny or the phylogeny. As an advocate of the antithetic theory of alternation of generations, Professor Bower does not accept the recapitulation theory. Hence the question of priority in the history of descent cannot be settled summarily by the sequence in the ontogeny. Neither an infinite number of transitional forms, nor experimentally the conversion of a sporophyll into a foliage leaf proves anything more than an intimate relationship between the two. It in no way settles phylogenetic priority.

A clue, the writer urges, may be obtained from the bryophytes. A comparison of the most primitive sporangium (Riccia) with more complex types indicates the intercalation of a seta before the spores are formed, and leads one to conclude that the seta does not precede spore development phylogenetically, but that in more complex capsules the spore development is retarded by an intercalated stage; in short, progressive sterilization and intercalation of vegetative parts takes place to provide for the growing demand for nutrition. In the genus Lycopodium a comparison of closely related forms and a study of the individual part has led the author to believe that the history of development is analagous to that of the bryophytes. By progressive sterilization the basal sporangia have become functionless and vestigial. The incomplete sporangia at the apex of the cone he regards as supernumerary, not in the same category with those at the base. Selaginella, Isoetes, and Equisetum are also discussed from the same standpoint. The author concludes that although abortive parts are less common in plants than in animals, and have played a less important rôle in theories of plant morphology than in zoology, they should not be left out of account altogether.—FLORENCE M. LYON.

F. E. LLOYD has filled an important gap in our knowledge of the essential morphology of angiosperms by his studies on the Rubiaceae. The first part, dealing chiefly with *Vaillantia hispida*, was issued August 26, 1899, and was noted in this journal.[14] The second part[15] now issued deals with numerous other forms, so that the conclusions are derived from a study of twenty-three species representing nine genera of Rubiaceae. In all forms, excepting species of Houstonia, the nucellus is very much reduced, not being distinguishable except at early stages, when it is a cap-like layer of cells covering the archesporium. As usual among the Sympetalae, the very small nucellus is

[14] BOT. GAZ. 29:292. 1900.

[15] LLOYD, FRANCIS E., The comparative embryology of the Rubiaceae. Mem. Torr. Bot. Club 8:27–112. *pls. 8–15.* 1902.

associated with a massive integument. In Houstonia the ovules have no integument, the archesporium becoming deeply imbedded by growth of the nucellar tissue. In the Spermacoceae an outgrowth derived from the funiculus is described as a "strophiole," and contains the vascular supply of the ovule. Throughout all the forms the archesporium contains seven to fifteen cells, the larger numbers occurring among the Galieae. Each spore mother cell forms the usual tetrad of four megaspores in linear series, but rarely are there any walls. In some cases two or more megaspores begin to function, sometimes in the same tetrad; ordinarily, however, the innermost megaspore of a central tetrad finally becomes the single embryo sac. The behavior of the embryo sac among the Galieae and in Diodia is quite remarkable, since it breaks through the nucellar cap and passes into the micropyle. The antipodals give evidence of more or less activity, among some of the forms one enlarging decidedly; among others division occurring so that there are four to ten antipodals; while in other forms they are ephemeral. Among the Galieae there is a remarkable suspensor, the cells elongating laterally or lateral branches arising and penetrating among the endosperm cells. It is another very interesting illustration of the various forms of haustorial development in connection with the embryo.

In the first division of the mother cell the spindle is multipolar in origin, and no centrosomes are to be found. In Crucianella and Asperula, whose cytological features were carefully studied, the reduced number of chromosomes is ten and twelve respectively; but after counting a large number of cases the writer believes that the number is not constant. In Asperula, in a late anaphase of the first division, the second longitudinal splitting of the chromosomes is already quite evident. In Crucianella this splitting takes place in the telophase. After the first division the daughter nuclei pass into a somewhat incomplete resting stage, no nucleolus being formed, and the nuclear membrane being quite indistinct. This division is heterotypic, but the second division, and also the divisions that occur during the germination of the megaspore, are homotypic. Judged from a cytological standpoint, the divisions which give rise to the row of four cells are true tetrad divisions, and the four cells are spores.

The memoir closes with a description of the behavior of the pollen tube in Diodia and Richardsonia, special stress being laid upon the determination of the course of the pollen tube.—J. M. C.

PROFESSOR GOEBEL has certainly earned the thanks of all students of evolution, and specifically of hybrids and plant-breeding, by reprinting the remarkable paper of Gregor Mendel on "Versuche über Pflanzen-hybriden.[16]

[16] Flora 89: 364–403. 1901. In a note of historical interest, Dr. Goebel states that the paper presented in 1865 and published in 1866 was long unknown to botanists. DeVries, Correns, and others made the re-discovery and pointed out its great value. It is now even more accessible, having found a place in Ostwald's "Klassiker der exakten Wissenschaften" as No. 121, published by Wilhelm Engelmann, 1901.

Artificial pollination to produce variations in color and the striking regularities that appeared in hybrid forms from the same crosses were the special features of Mendel's work, which had for its object a study of the development of hybrids in their offspring. Mendel is not surprised at the new discovery of a generally valid law for the formation and development of hybrids, considering the great difficulties involved. No previous work, as he points out, was carried on in such a manner as to allow of the determination of the number of the different forms in which the offspring of hybrids appear, and to show that these forms can be classified with certainty in the several generations and the mutual numerical conditions determined; although such comprehensive study is the only way finally to solve a question which, in the evolution of organic forms, is of no mean importance.

The reasons for selecting the genus Pisum are given, and from thirty-four varieties of peas twenty-two were selected for the experiments, after a two-year test had shown them to be constant in their offspring. To study the changes in the inheritance of different characteristics, and to determine the law according to which these differences appear in the succeeding generations, were the objects of the experiment, and the latter object would constantly divide itself into as many experiments as there were constant different characteristics in the plants selected. Of such characteristics there were studied: the differences in the shape of the ripe seed; differences in the color of the endosperm, and in the color of the seed coats; differences in the form of the ripe pods and the color of the unripe pods; differences in the position of the flowers; and finally differences in the length of the axes.

Earlier experiments had shown that hybrids[17] were not, as a rule, exact averages of the parents. Often certain prominent characteristics appeared to such an extent that another characteristic would be rare or even absent. This was the case with the Pisum species. Mendel classifies such characteristics as dominating and recessive ("dominirende und recessive"). All experiments showed that it was immaterial whether the dominating characteristic was in the seed parent or in the pollen parent. Of the differing characteristics, the following were dominant: (1) the round or roundish seed with or without shallow depressions; (2) the yellow color of the endosperm; (3) the gray, gray-brown, or leather-brown color of the seed-coat, in combination with a violet reddish flower and reddish spots in the leaf axils; (4) the simple domed form of the pod; (5) the green color of the unripe pods in combination with the green color of the stems, the ribs of the leaves, and the calyx; (6) the distribution of flowers along the stems; (7) the length of the longer axis.

The first generation of hybrids, in addition to the dominating characteristics, showed also the recessive characteristics in their peculiarities, and in

[17] Hybrids (Hybriden) is used in the paper in the sense of "cross."

the decisively apparent average of 3:1, *i. e.* of four plants of this first generation three had the dominating and one the recessive character. This was true without exception for all characters which were considered. Intermediate forms were not noticed in any of the experiments. As an example may be mentioned that in the first experiment, from 253 hybrids 7324 seeds were had in the second year. Of these, 5474 were round or roundish, and 1850 were angular and wrinkled, resulting in a ratio of 2.96:1. In the second experiment, 258 plants gave 8023 seeds, of which 6022 were yellow, and 2001 green, giving a ratio of 3.01:1. The other ratios were for (3) 3.15:1, (4) 2.95:1, (5) 2.82:1, (6) 3.14:1, (7) 2.84:1. For the whole series the ratio was 2.98:1, or practically 3:1.

The second generation showed that these forms, which in the first generation had exhibited the recessive character, did not vary in this character. They remained constant or fixed. Of those with the dominant characteristic in the first generation, two parts gave offspring which in the ratio of 3:1 carry the dominant and recessive characteristics, *i. e.* the same relation as the hybrid forms; and only one part remained constant with the dominant characteristics. In the first experiment of this series, 565 plants from round seeds of the first generation gave 193 with none but round seeds — and were therefore constant in this characteristic, — 372 gave round and angular seeds in the ratio of 3:1. The number of hybrids was therefore to the number of constants as 1.93:1. In the second experiment the relations were 3:1 and 2.13:1. In the succeeding experiments the number of plants was reduced, but the ratios as a whole remained constant, although showing greater variations.

The ratio 3:1 in the first generation becomes for all the experiments 2:1:1, distinguishing the dominating characteristic both as an original and a hybrid character. As the members of the first generation come directly from the seed of the hybrids, it is now seen that the hybrids of each two differing characteristics gave seed of which one-half again developed the hybrid character, while the other gave plants which remained constant and exhibited in equal parts the dominating and recessive character.

The first and second experiments carried through six generations, the third and seventh through five, and the fourth, fifth, and sixth, through four generations, show the ratio of 2:1:1, although beginning with the third generation only a small number of plants was used. If, then, A represent one of two constant characteristics, *e.g.* the dominating one, the recessive designated by a, and Aa the hybrid form in which both characteristics are united, there results the expression $A+2Aa+a$ for the developmental series of the offspring of hybrids with two differing characteristics. The tendency of hybrids to revert to the parental type is explained by this expression. In the case of two and three differing characteristics, it was found that the hybrids were closer to such parents as had the greater number of dominating characteristics. Designating the seed parent by AB, the pollen parent by ab, the

round seed by A, the angular seed by a, the yellow endosperm by B, and the green endosperm by b, then the relations as found by experiment were expressed by the term $AB+Ab+aB+ab+2ABb+2aBb+2AaB+2Aab+4AaBb$, or a combination of $A+2Aa+a$ and $B+2Bb+b$. For three differing characteristics the combination was $A+2Aa+a$, $B+2Bb+b$, $C+2Cc+c$.

With some further experiments, Mendel then concludes that the offspring of hybrids, in which several essentially different characteristics are united, are the members of a series of combinations in which each two differing characteristics are combined in a developmental series. This at the same time proves that the behavior of two differing characteristics in hybrid combination is independent of other variations in the two parents. Developing his mathematics still further, he shows that if n designate the number of characteristic differences in the two parent plants, then 3^n is the number of the terms in the combination, 4^n the number of the individuals, and 2^n the number of the combinations that remain constant. The foregoing results led to attempts at experimental proof of the theory that the ovary of the hybrid contains as many germ cells and the anthers as many pollen cells as constant forms of combination are possible. This was shown for peas, as indicated in the results.

Experiments with *Phaseolus vulgaris* and *P. nanus* gave results corresponding to those already mentioned, but only partially corroborative results were had with *Phaseolus nanus* as seed parent and *P. multiflorus* as pollen parent. In this latter experiment the changing color caused some interesting observations and speculations on the theory of this change in accordance with the results developed in other experiments.

The concluding pages deal with the work of Kölreuter and Gärtner, especially along the lines of Mendel's experiments, and finally with a discussion of the changing of one variety into another by means of artificial pollination.—G. N. LAUMAN.

NEWS.

THOMAS COMBER, the well-known English botanist, died at Blackpool, January 24.

DR. B. M. DUGGAR, of the Bureau of Plant Industry, has been elected Professor of Botany at the University of Missouri.

DR. A. JAKOWATZ has been appointed Assistant at the Botanical Museum and Garden of the University of Vienna.

THE ADVISERS IN BOTANY for the Carnegie Institution are F. V. Coville, N. L. Britton, Gifford Pinchot, and J. M. Macfarlane.

ACCORDING TO *Science*, 83,000 acres of forest land have been purchased by the State Forestry Commission in central Pennsylvania.

THE DEGREE OF LL.D. has been conferred upon B. T. Galloway, Director of the Bureau of Plant Industry, by the University of Missouri.

A NEW EDITION of Oliver's translation of Kerner's *Pflanzenleben* is announced by Blackie & Son, London, at a considerably reduced price.

A BIOGRAPHICAL SKETCH of Lewis D. von Schweinitz, with a portrait, written by C. L. Shear, is published in the March number of *Plant World*.

DR. OLIVER R. WILLIS, the editor and reviser of Alphonso Wood's botanical texts, died April 27, at White Plains, N. Y., at the age of 87 years.

ERNST A. BESSEY, of the Bureau of Plant Industry, will sail early in July to secure seeds of forage plants and cereals in Russia, the Caucasus, and Turkestan.

A BIOGRAPHICAL SKETCH of the late Alfred W. Bennett, written by J. G. Baker, and accompanied by a portrait, is published in the April number of *Jour. Roy. Micr. Soc.*

PROFESSOR A. ZIMMERMANN, until recently at Buitenzorg, has been appointed botanist at the biological station at Amani, Post station Tanga, Dutch East Africa. He was to reach his station about the middle of April.

IN *Malpighia* (15: 297–324. 1902) there are published the memorial addresses delivered January 5 last in connection with the establishment of the bust of Giuseppe Gibelli, formerly of the Botanical Institute of Torino. The chief speaker was Professor R. Pirotta, of the Royal Botanical Institute of Rome.

THE BOTANICAL SOCIETY OF AMERICA will hold its eighth annual meeting at Pittsburg, Pa., June 30 to July 2, under the presidency of Dr. J. C. Arthur. The business sessions will be held in the Hotel Schenley, and the

program of scientific papers will be given in Phipps' Botanical Hall, beginning at 11 A. M., July 1.

THE INCREASING OPPORTUNITIES for the investigator at the Royal Botanic Garden, Peradeniya, Ceylon, become apparent in the recent annual report of Director J. C. Willis. During 1901, in addition to visits for administrative purposes, W. H. Lang and A. G. Tansley secured important results and material at the garden.

THE BILL AUTHORIZING the establishment of a biological station on the Great Lakes by the Commissioner of Fish and Fisheries has passed the Senate. The selection of a suitable site involves an investigation of the claims of eight states, and for this purpose, as well as to secure the necessary land and water rights, an appropriation of $10,000 has been made.

G. S. JENMAN, Government Botanist of British Guiana, died at Georgetown February 28. His previous position (1873-1879) was superintendent of the botanical garden at Castleton, Jamaica. He was especially familiar with the ferns of British tropical America, and at the time of his death was publishing a conspectus of them in parts, five of which had appeared.

DURING THE YEAR 1901 accessions to the herbaria of the New York Botanical Garden amounted to 55,747 sheets, representing 77,657 specimens. In the various plantations and conservatories the number of species in cultivation was as follows: public conservatories 3344, herbaceous grounds 3012, fructicetum 512, arboretum 169, pinetum 16, salicetum 43, viticetum 65.

DR. B. E. LIVINGSTON and MR. H. N. WHITFORD, Assistants in Botany, and MR. C. D. HOWE, Fellow in Botany, of the University of Chicago, have been appointed collaborators in the Bureau of Forestry, Department of Agriculture, for the year beginning July 1, 1902. Dr. Livingston will work on some forest problems in the northern part of the southern peninsula of Michigan; Mr. Whitford will continue some investigations already begun in the forests of the Rocky mountains in the northwestern part of Montana; and Mr. Howe will do similar work in the vicinity of Burlington, Vermont.

THE THIRD REPORT (1901) of the Michigan Academy of Science contains the following botanical papers: Transition from stem to root in *Echinocystis lobata*, by J. B. POLLOCK; Ecological study of a glacial lake near Ann Arbor (abstract), by H. S. REED; A disease of the white birch, by JOHN LARSEN; Interfoliar scales of monocotyledonous aquatics (abstract), by MINNA C. DENTON; Notes on the flora of Eaton co., by H. L. CLARK; Forests of northern Michigan (abstract), by W. J. BEAL; A noteworthy occurrence of Wolffia, and Notes on *Utricularia cornuta*, by C. A. DAVIS; Notes on Michigan saprophytic fungi, New species of Michigan fungi, and A sclerotium disease of the huckleberry, by B. O. LONGYEAR; Causes inducing asparagus to take its form of growth, by L. LENORE CONOVER.

GENERAL INDEX.

The most important classified entries will be found under Contributors, Personals, and Reviews. New names and names of new genera, species, and varieties, are printed in **bold-face type**; synonyms in *italics*.

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